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# Lawrence Livermore National Laboratory's Book of Minimum Detectable Activity for Direct Measurement of Internally Deposited Radionuclides in Radiation Workers - CY2011

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# INTRODUCTION

Lawrence Livermore National Laboratory maintains an in vivo measurement program designed to identify and evaluate the activity of radionuclides deposited in the body. Two types of systems are primarily used for the routine monitoring of radiation workers, the lung counting system and the scanning bed whole body counting system.

The lung counting system is comprised of two Canberra ACTII detector sets. Each ACTII set contains two planar germanium detectors with carbon composite end windows optimized to measure low energy photon emitting radionuclides. The ACTII detectors are placed on the upper torso over the lungs for the direct measurement of internally deposited radionuclides in the lungs that emit low energy photons. A correction for the thickness of the chest wall is applied to obtain the efficiency. Because the thickness of the chest wall is a key factor in the measurement of low energy photon emitting radionuclides in the lung, the minimum detectable activity is a function of the chest wall thickness.

The scanning bed whole body counting system is comprised of a thin air mattress on top of a carbon fiber bed that slowly scans over four high purity germanium detectors. The scanning system is designed to minimize variations in detected activity due to radionuclide distribution in the body. The scanning bed detection system is typically used for the measurement of internally deposited radionuclides that emit photons above 100 to 200 keV. MDAs have been generated for radionuclides that provide energies above 80 keV since the lowest calibration energy for the system is approximately 86 keV.

The MDA is evaluated using personnel in vivo measurements that were performed between January and December 2011. All positively identified peaks were eliminated from the evaluation. In routine in vivo spectral analysis, each person provides their own background continuum (or control sample) that is applied as the background for the measurement. Each person will have a varying background according to Compton contributions from higher energy natural radionuclides contained within the body. This Compton contribution is most notable in low energy photon measurements such as lung counting. Likewise, the efficiency of measurement for low energy regions (on the ACT II detectors) is highly influenced by overlying tissue composition and thickness. Finally, as the overlying tissue thickness increases, the distance of the detector from the source material increases. All of these factors influence the MDA and are accounted for by using personnel measurements wherein photon peaks of interest were not identified. MDA was computed using the Canberra software routines. If a peak is unidentified the MDA (in  $\mu\text{Ci}$ ) is evaluated using:

$$MDA = \frac{2.71 + 4.65 * \sqrt{B}}{k * \epsilon * b * E_1} * e^{\lambda T_s} * \frac{\lambda * E_r}{(1 - e^{-\lambda E_r})}$$

Where:

B = background sum count

k = 37000 (Bq/μCi)

ε = detection efficiency (γ detected/ γ emitted)

b = gamma photon abundance

E<sub>1</sub> = elapsed live time (seconds)

λ = radionuclide decay constant (seconds<sup>-1</sup>)

T<sub>1/2</sub> = half-life of nuclides (seconds)

E<sub>r</sub> = elapsed real time (seconds)

T<sub>s</sub> = sample date – acquisition start time

The background sum count is determined as 1.5 times the predicted full width at half maximum (FWHM) on either side of the predicated peak centroid. This method of MDA determination is an expanded version of the MDA methodology presented in Appendix A of the ANSI 13.30, Performance Criteria for Radiobioassay (1996). The expanded version more specifically defines the components of the constants in the denominator of the MDA equation and provides for radionuclide decay since the sample time as well as radionuclide decay during acquisition.

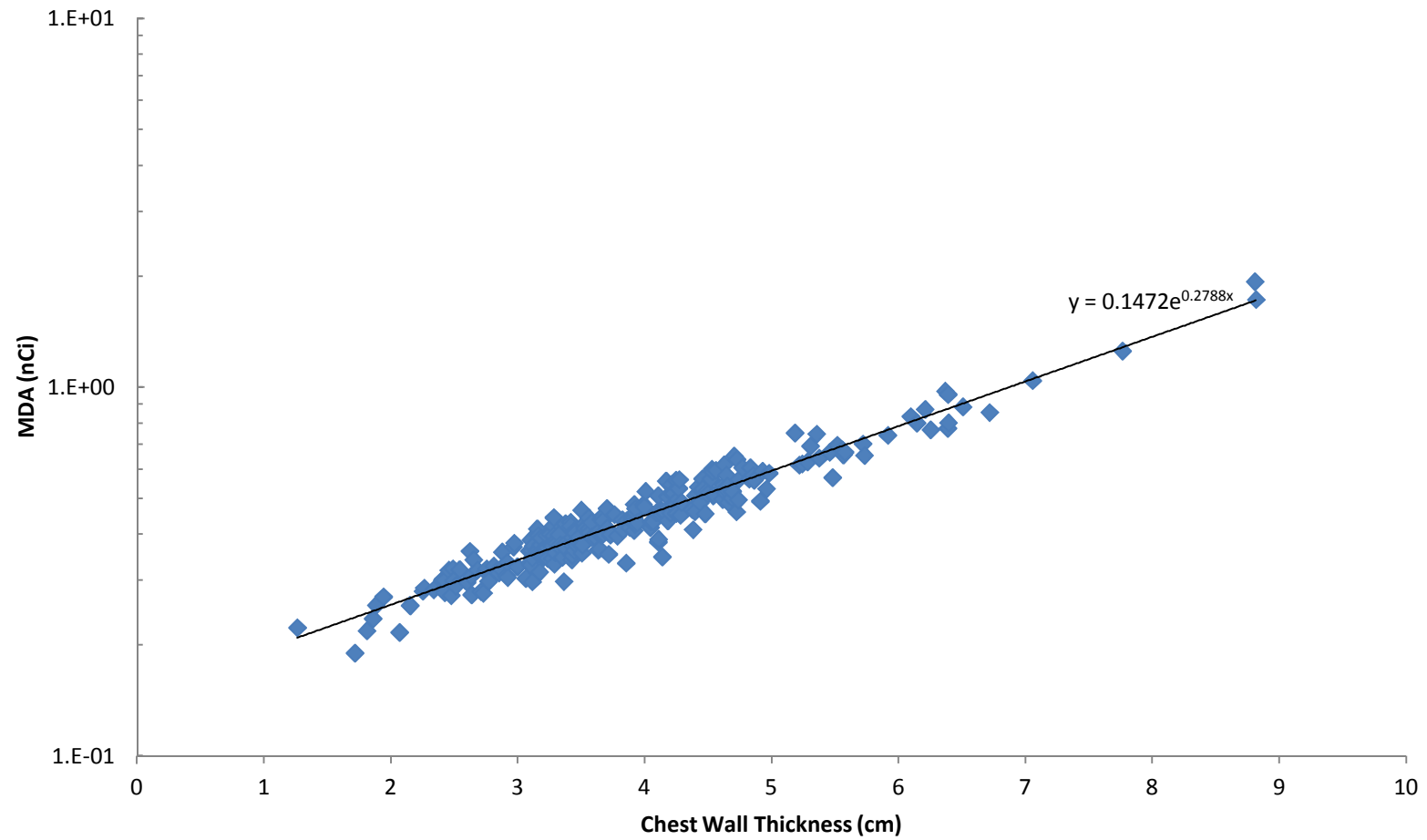
The following charts and table provide best determination of minimum detectable activity using human subjects as controls for the background contributions. A wide variety of radionuclides are used throughout the laboratory and the following pages represent several of the radionuclides that have been encountered at the Whole Body and Spectroscopy Laboratories within Hazards Control. When multiple photon energies are necessary to determine the minimum detectable activity for varying overlay tissue thickness, the appropriate energy lines have been included. When multiple photon energies are used to assess the minimum detectable activity, the estimated transition thickness from one photon energy to another is noted where appropriate. Some charts also include the MDA of the nearest confirmatory photon peak(s) that would have to be present to truly assure positive identification of the radionuclide. Multiple energy MDA curves are presented for some radionuclides where these energies might be used for confirmation of detection.

This evaluation of MDA for CY2011 partially covers a period when the environmental background was known to be elevated due to failures in the high efficiency particulate air (HEPA) filtration on inlet air into the counting facility. MDAs in this evaluation are higher than previous evaluations.

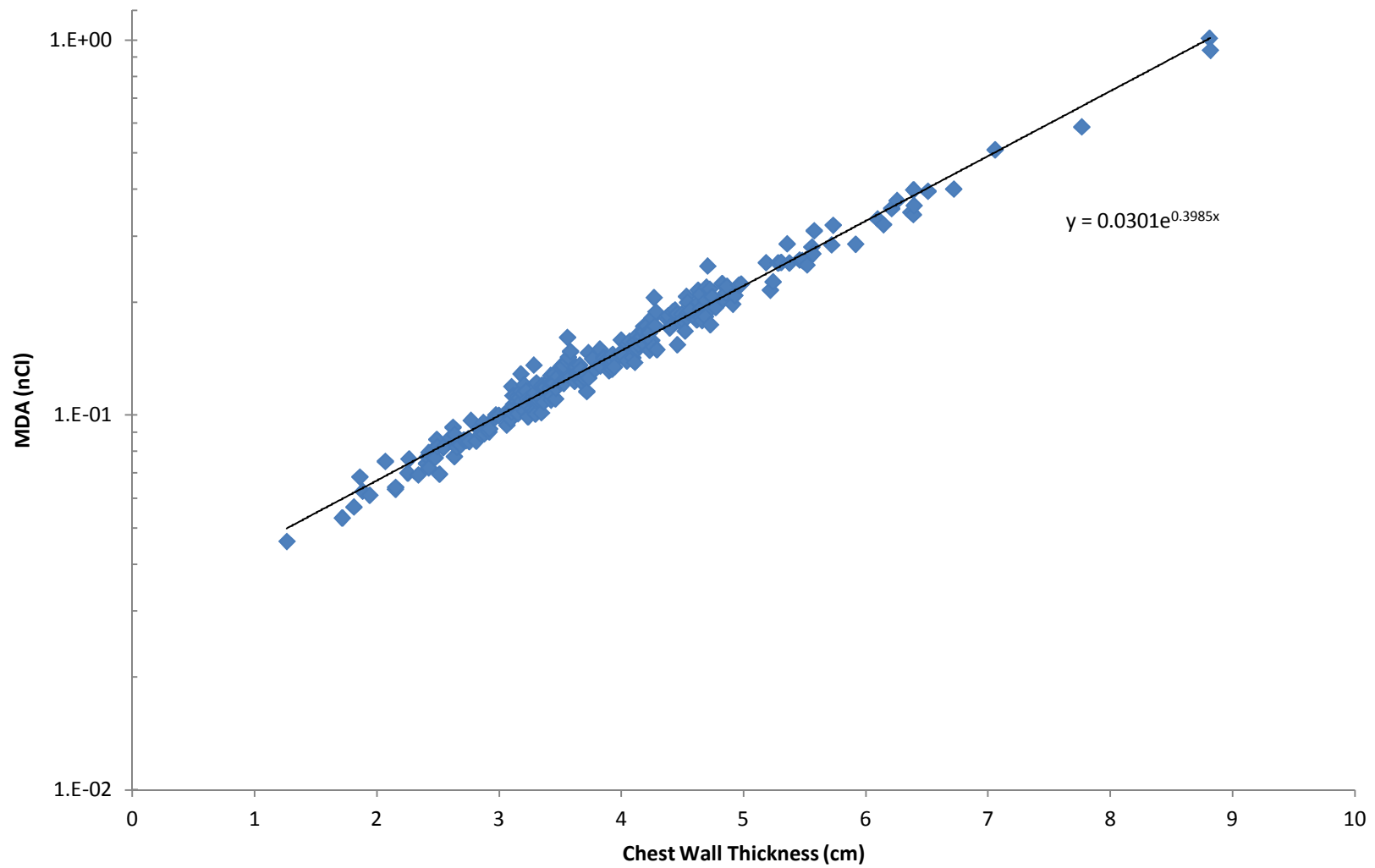
# LUNG COUNTING MINIMUM DETECTABLE ACTIVITIES



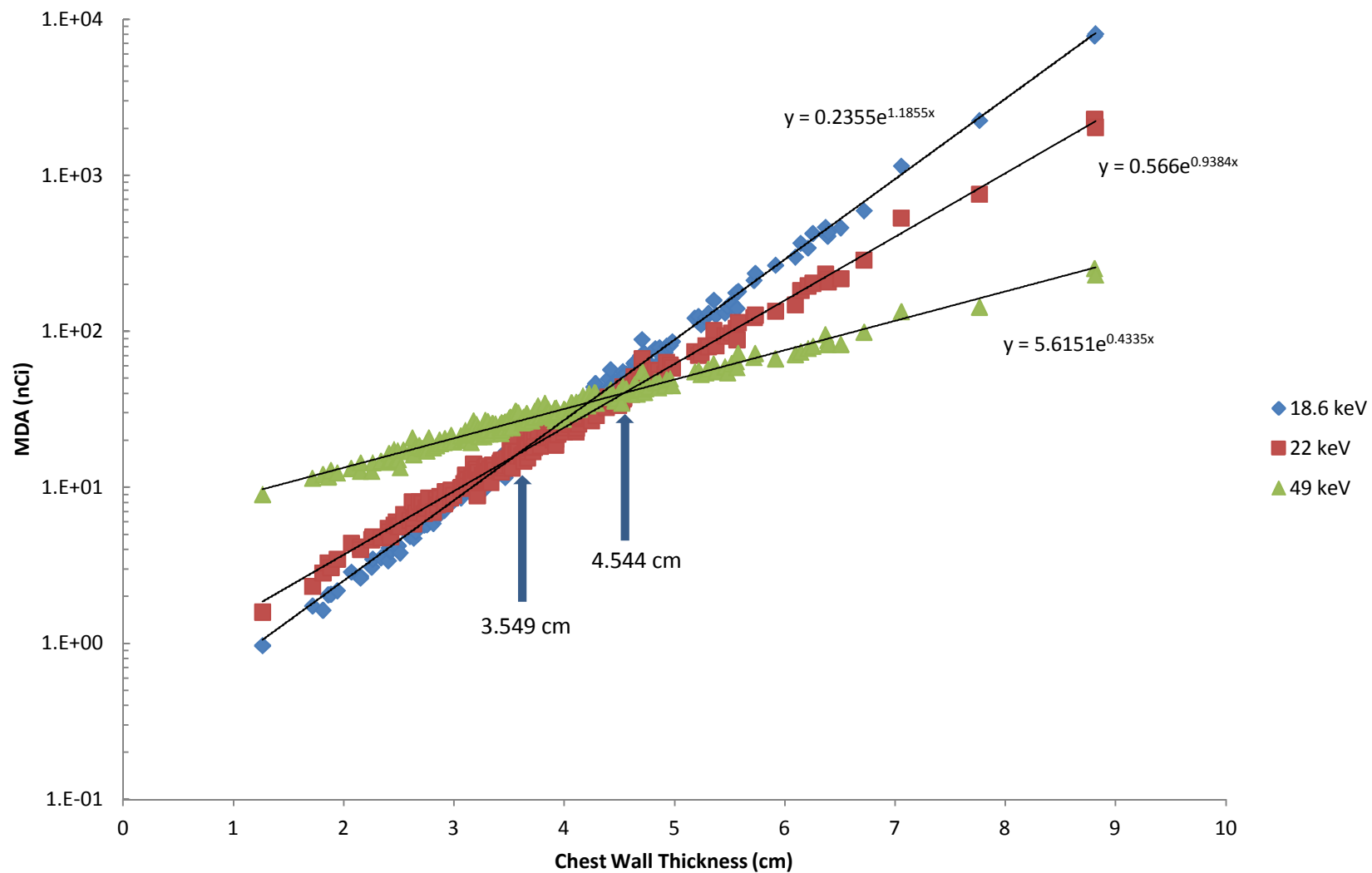
## Lung Count Ac-228 Minimum Detectable Activity



## Lung Count Am-241 Minimum Detectable Activity

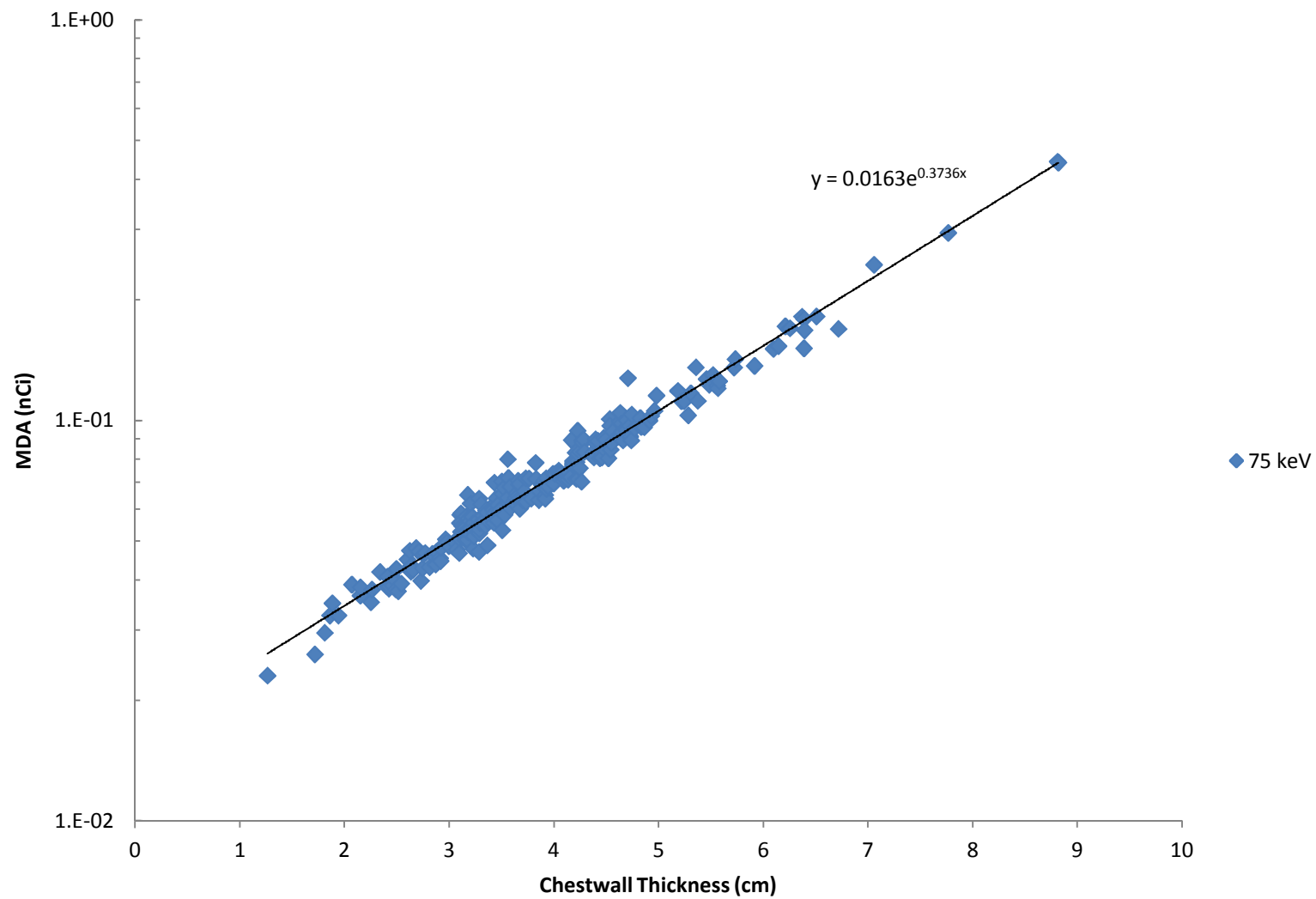


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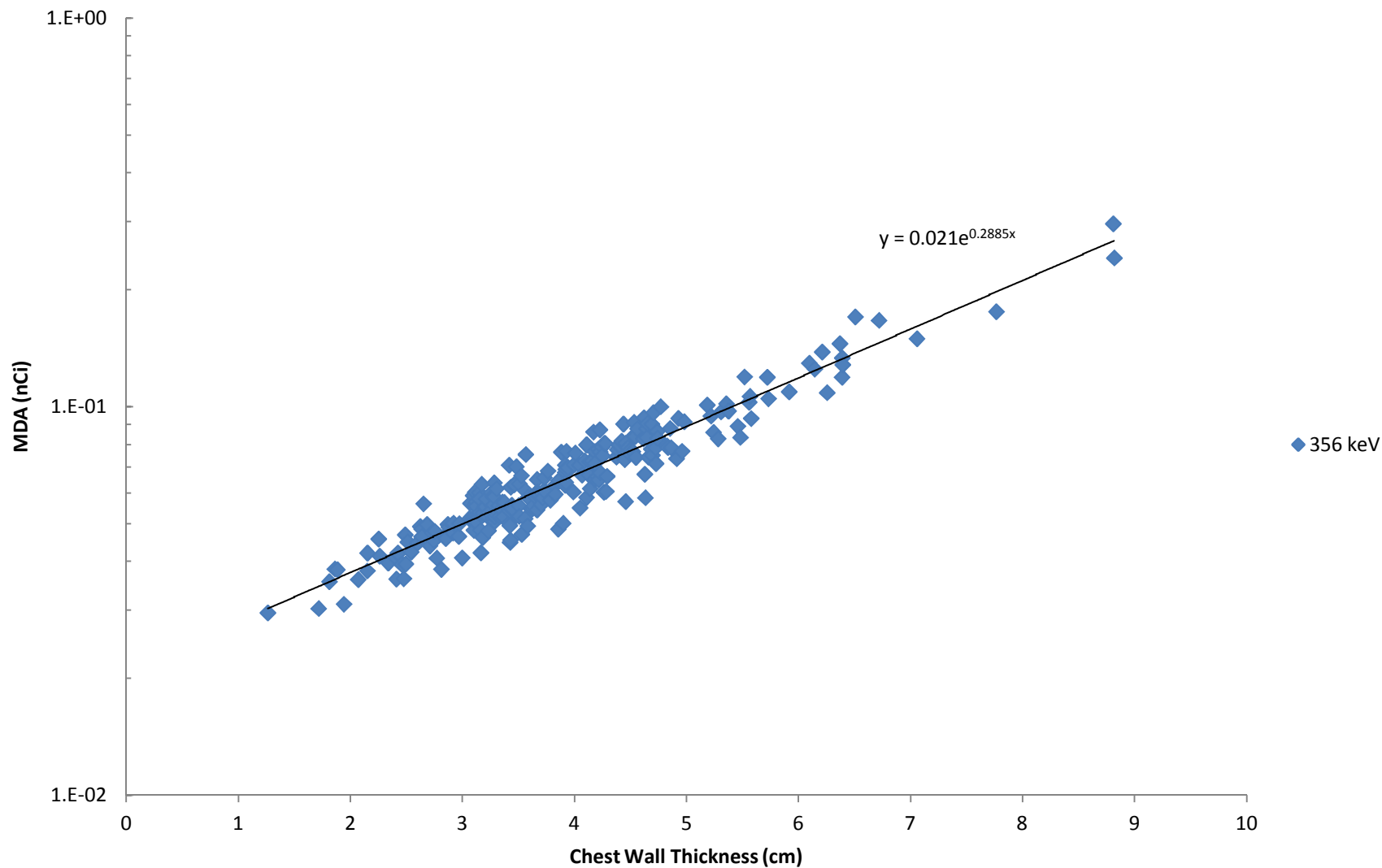




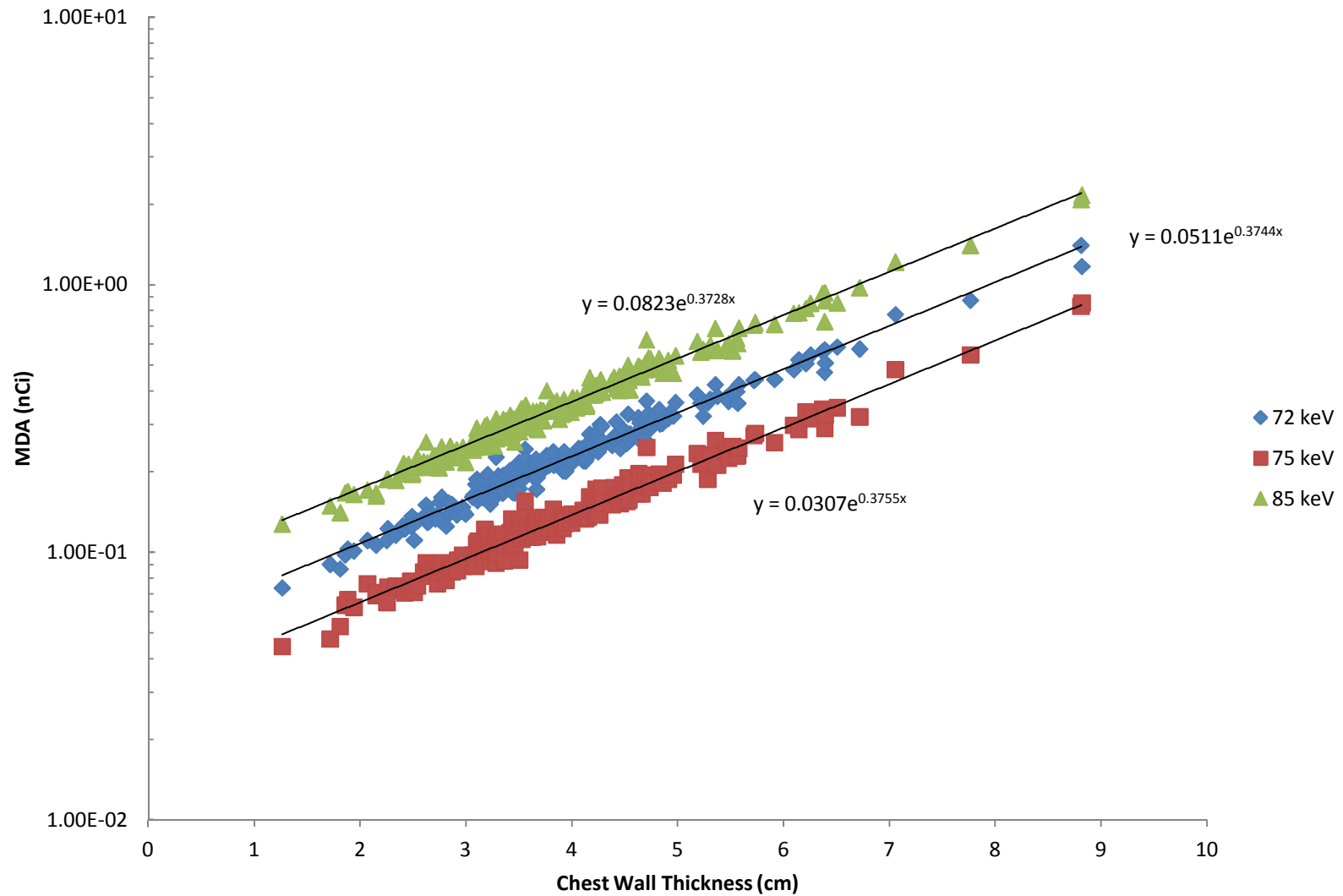
## Lung Count Am-243 Minimum Detectable Activity



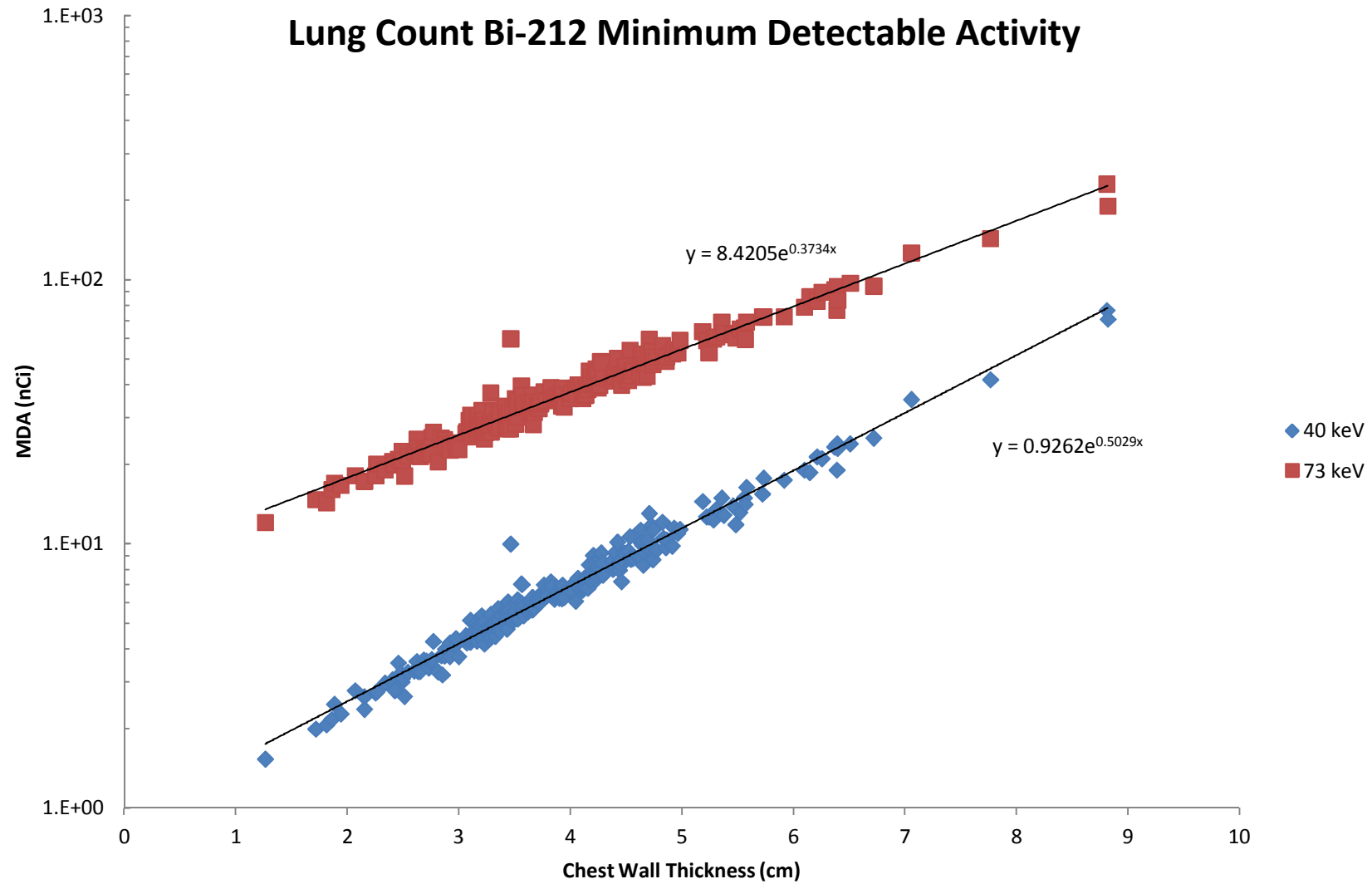
## Lung Count Ba-133 Minimum Detectable Activity



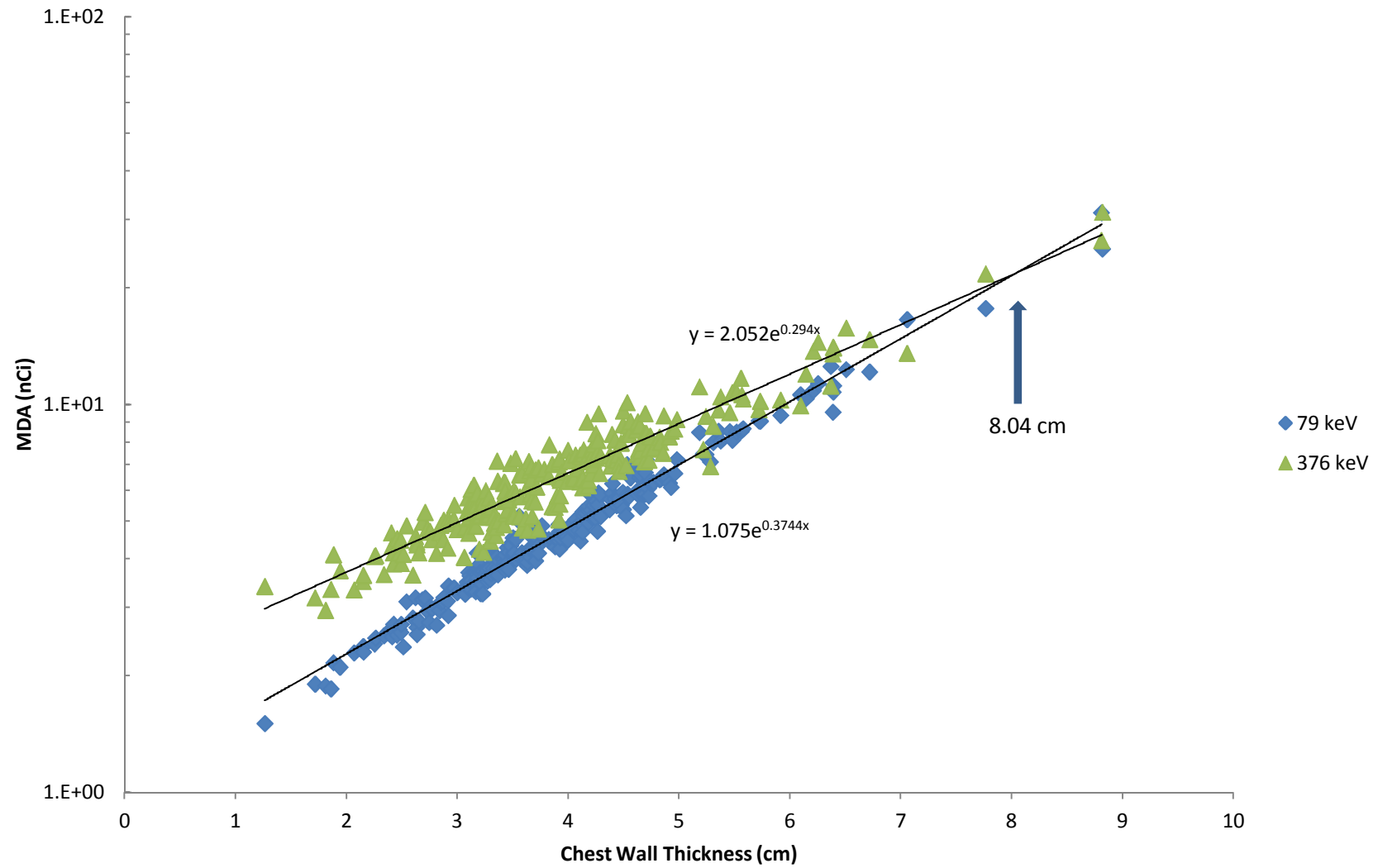
## Lung Count Bi-207 Minimum Detectable Activity



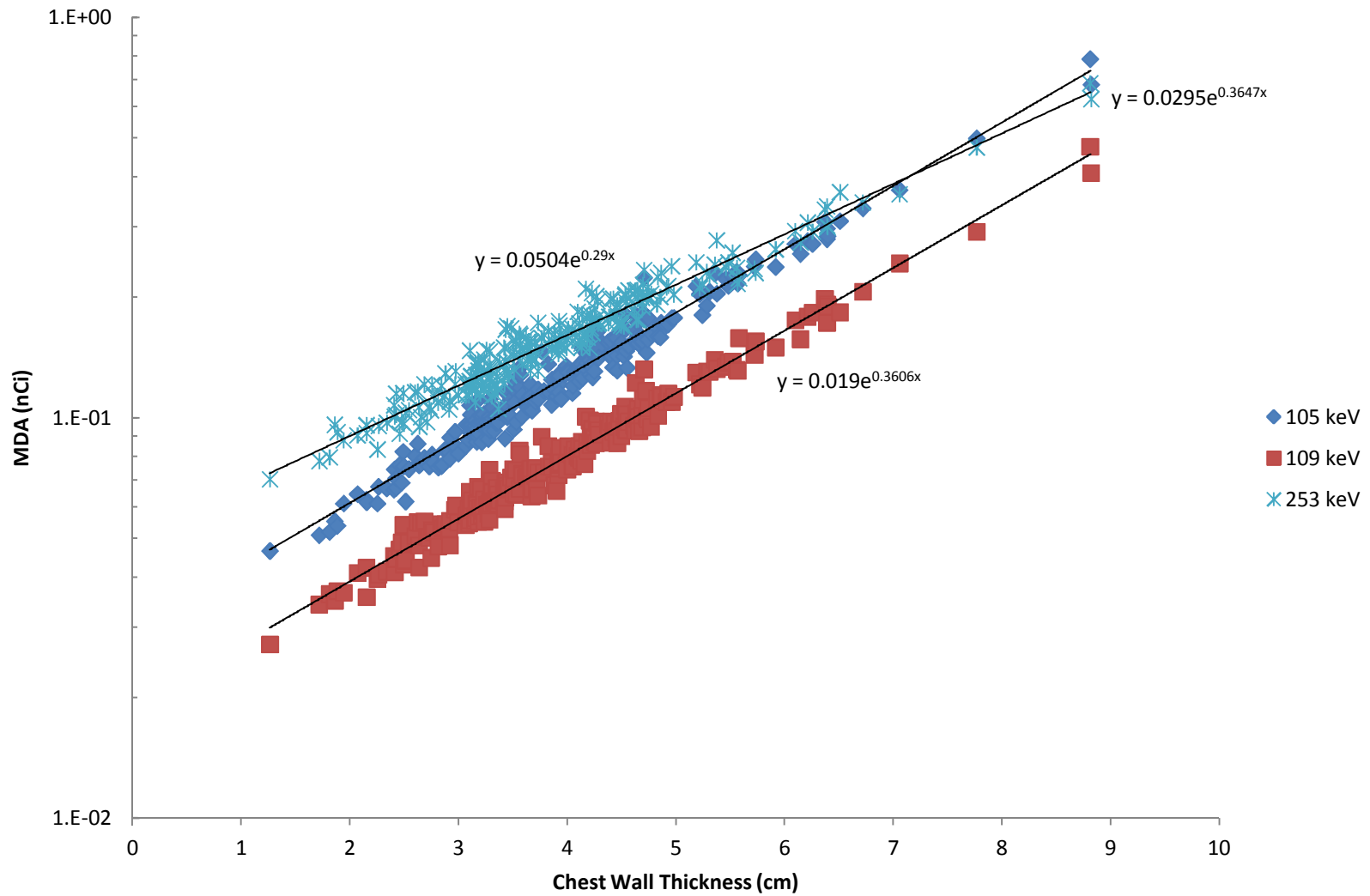
## Lung Count Bi-212 Minimum Detectable Activity



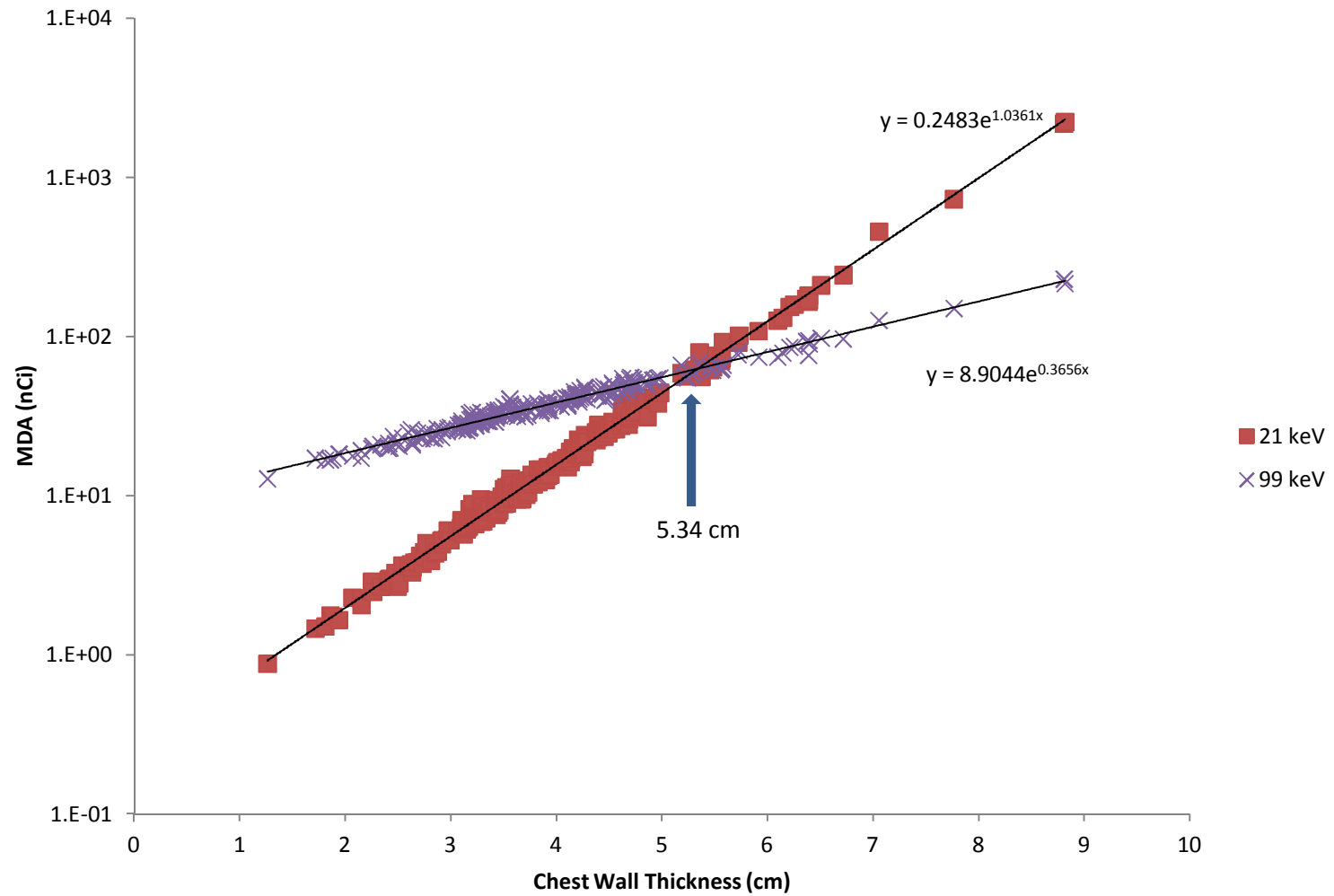
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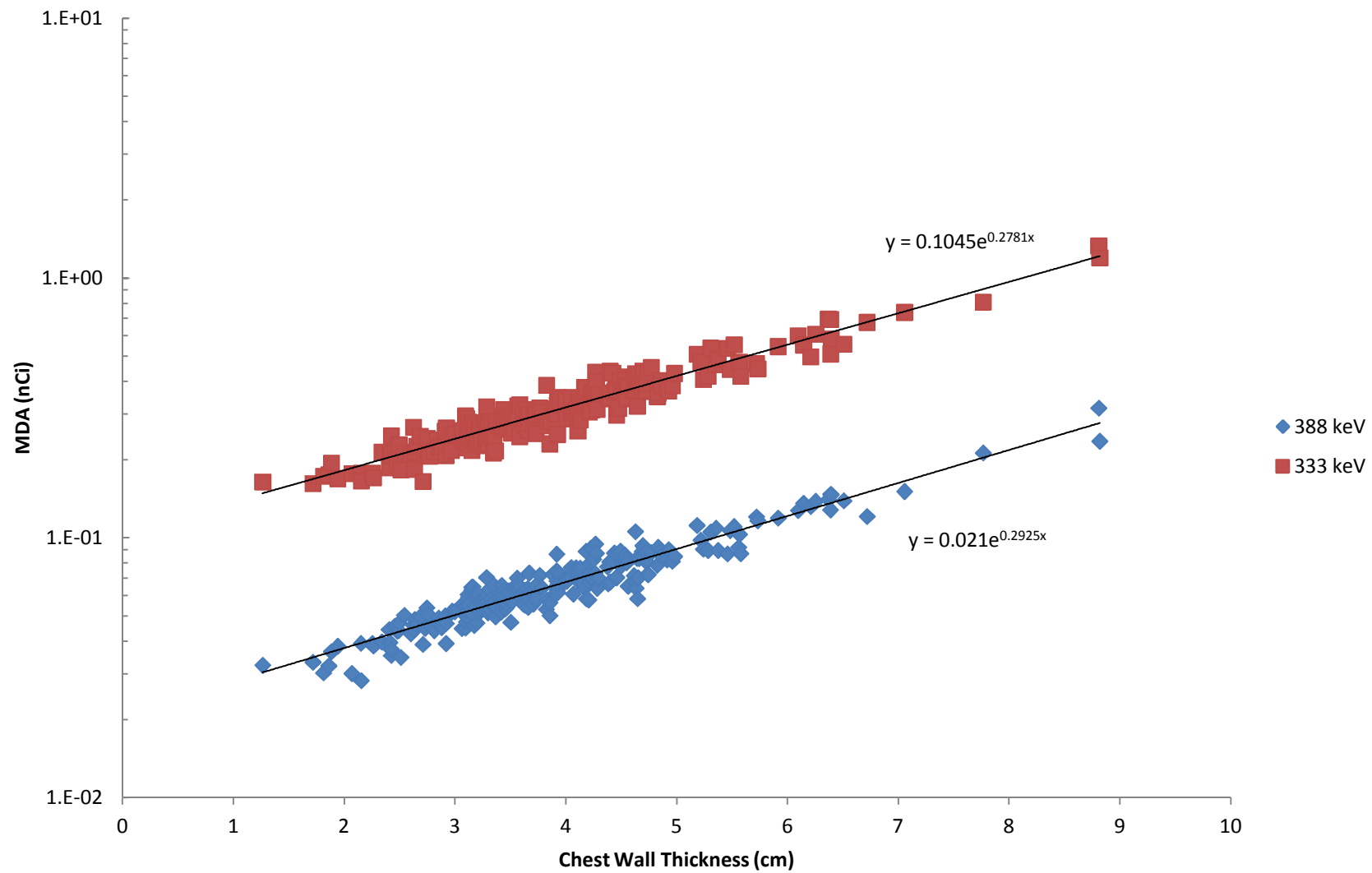
## Lung Count Bk-245 Minimum Detectable Activity



## Lung Count Bk-250 Minimum Detectable Activity

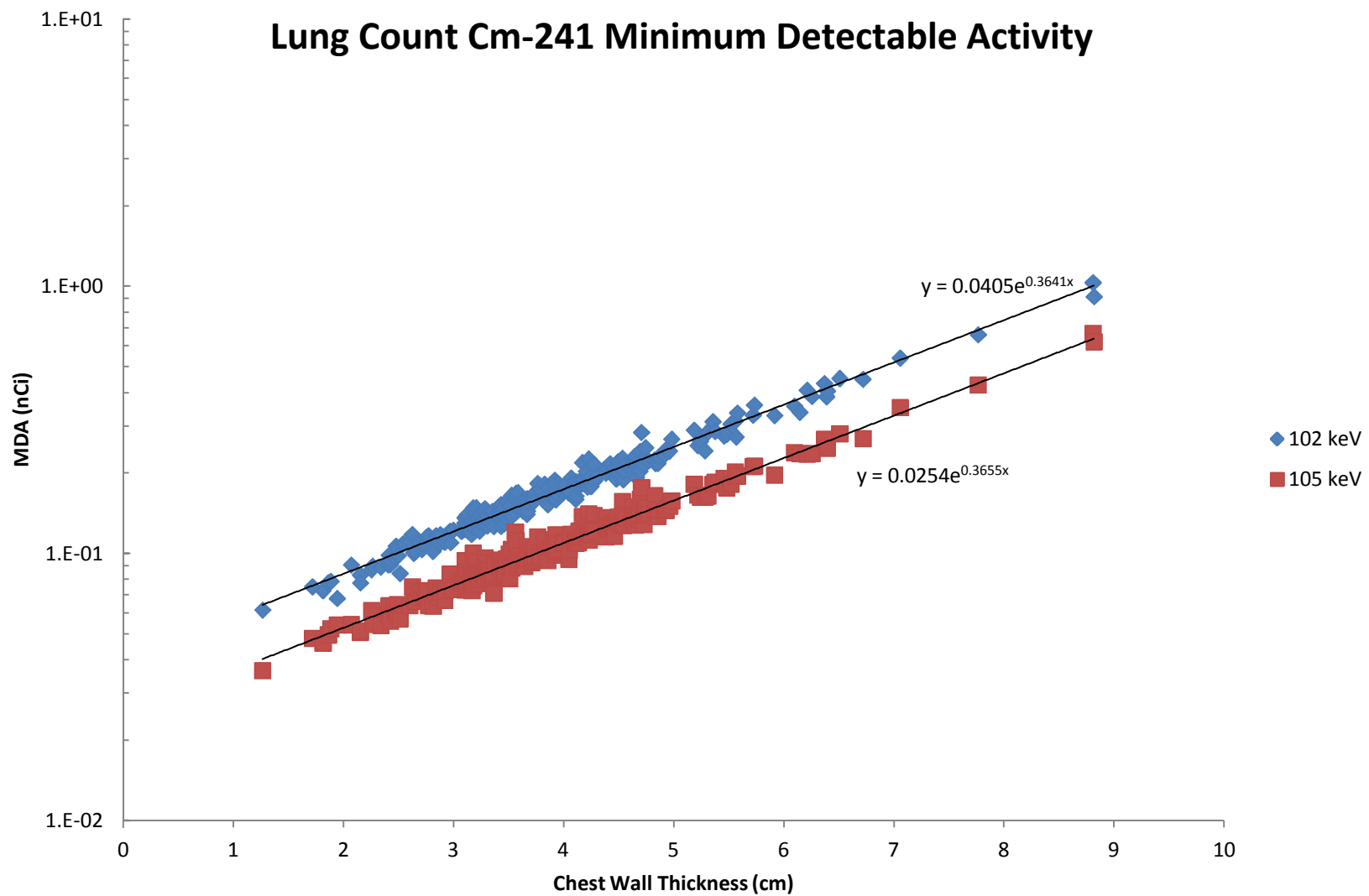


## Lung Count Cf-249 Minimum Detectable Activity

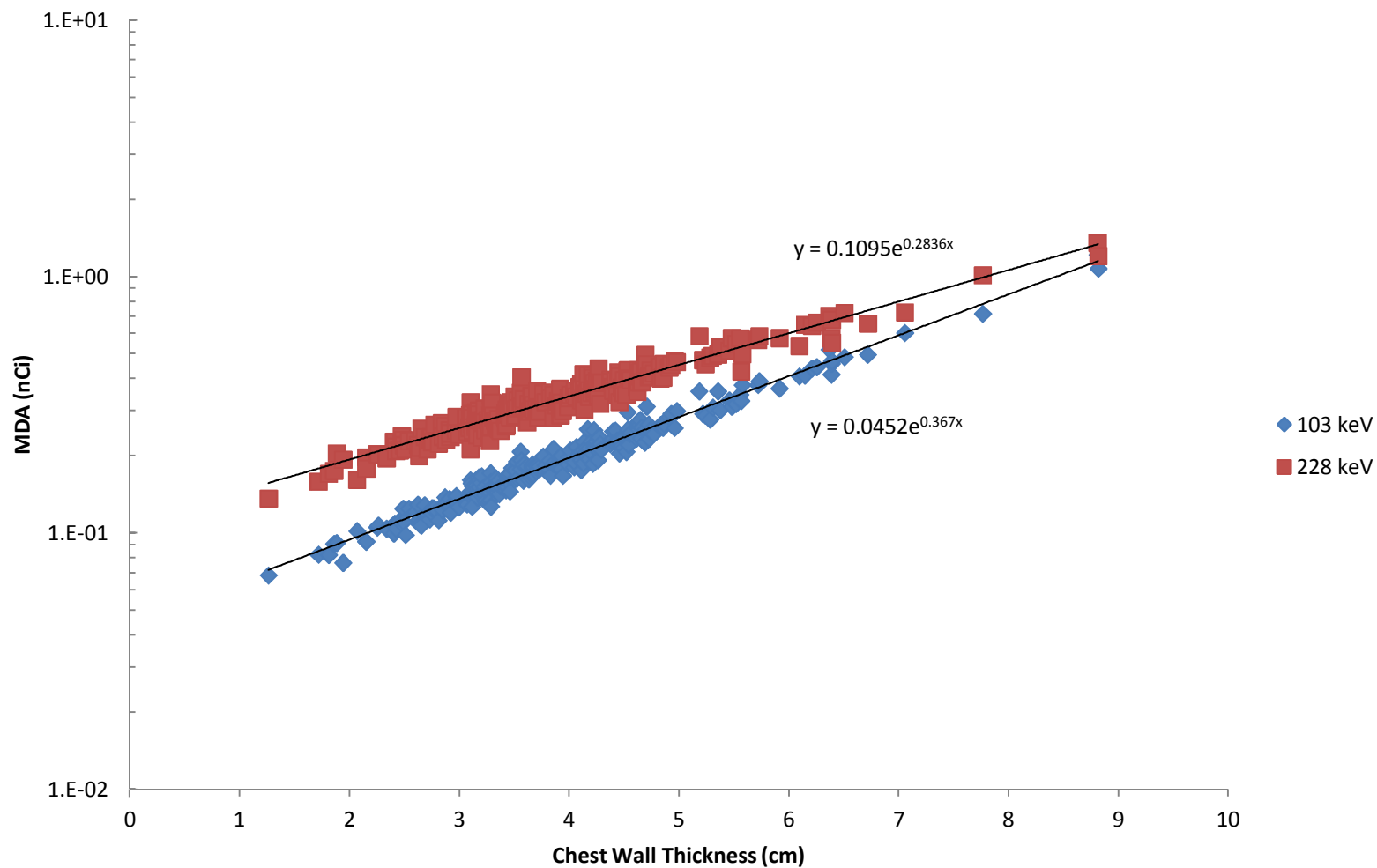




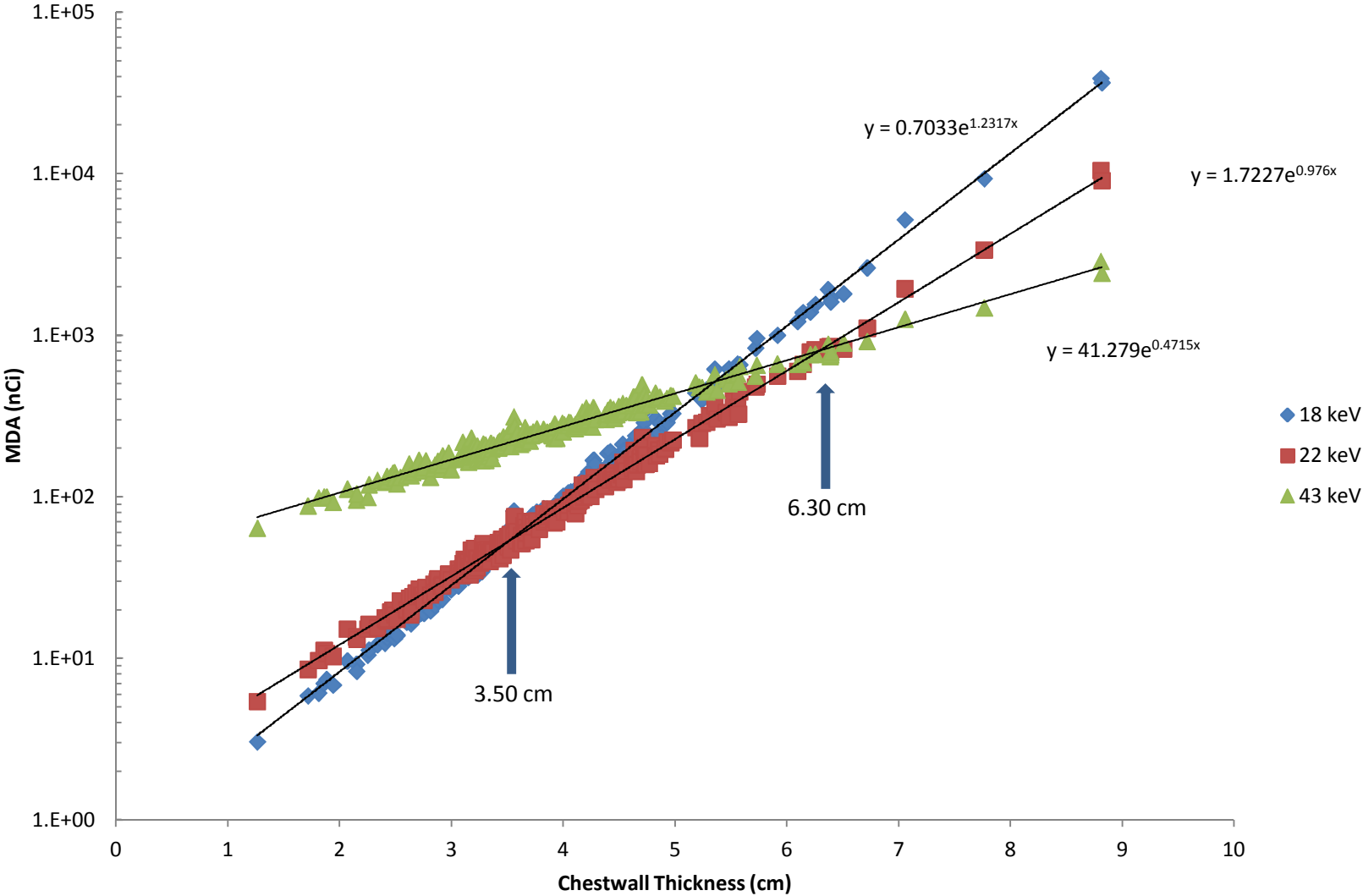
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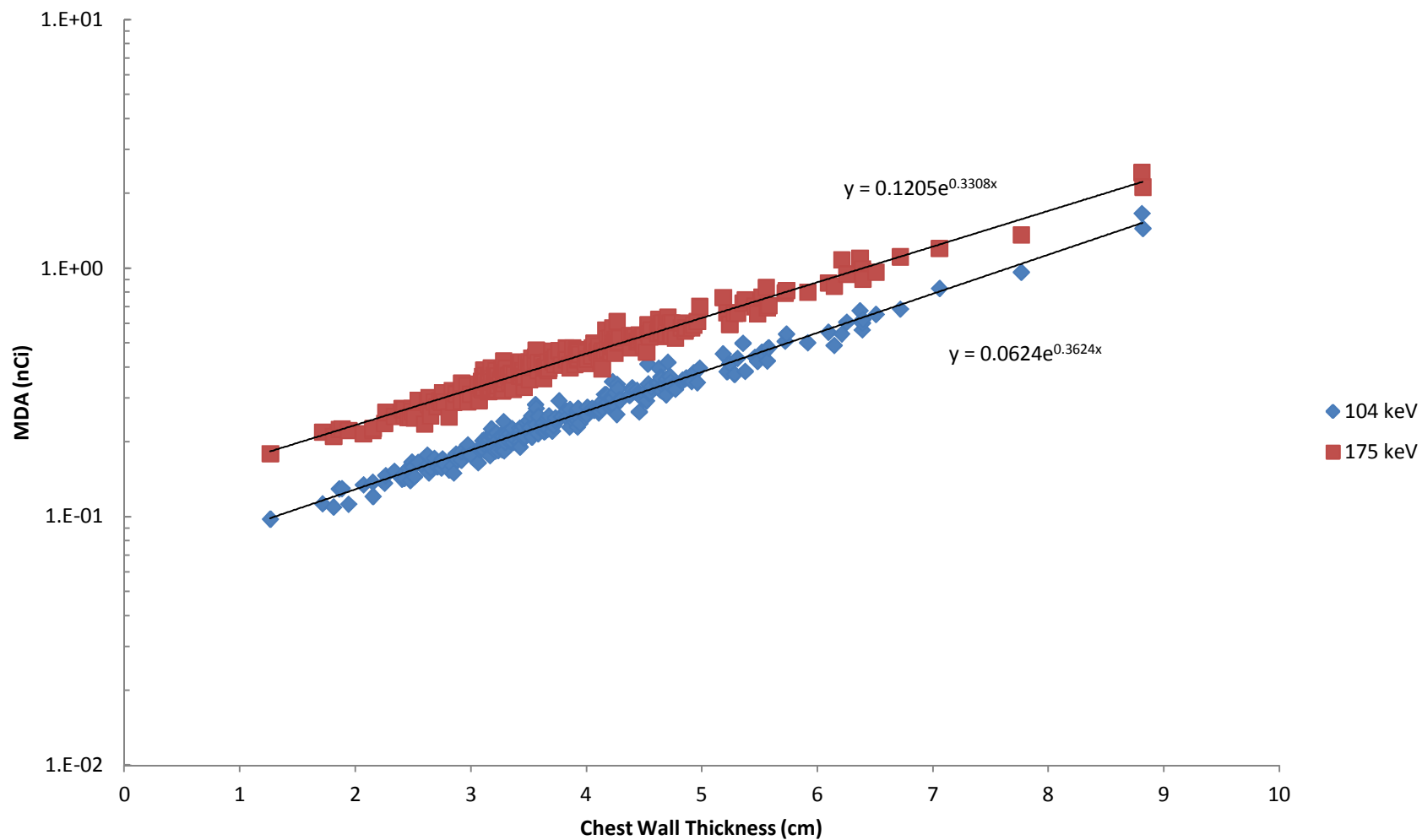
## Lung Count Cm-243 Minimum Detectable Activity

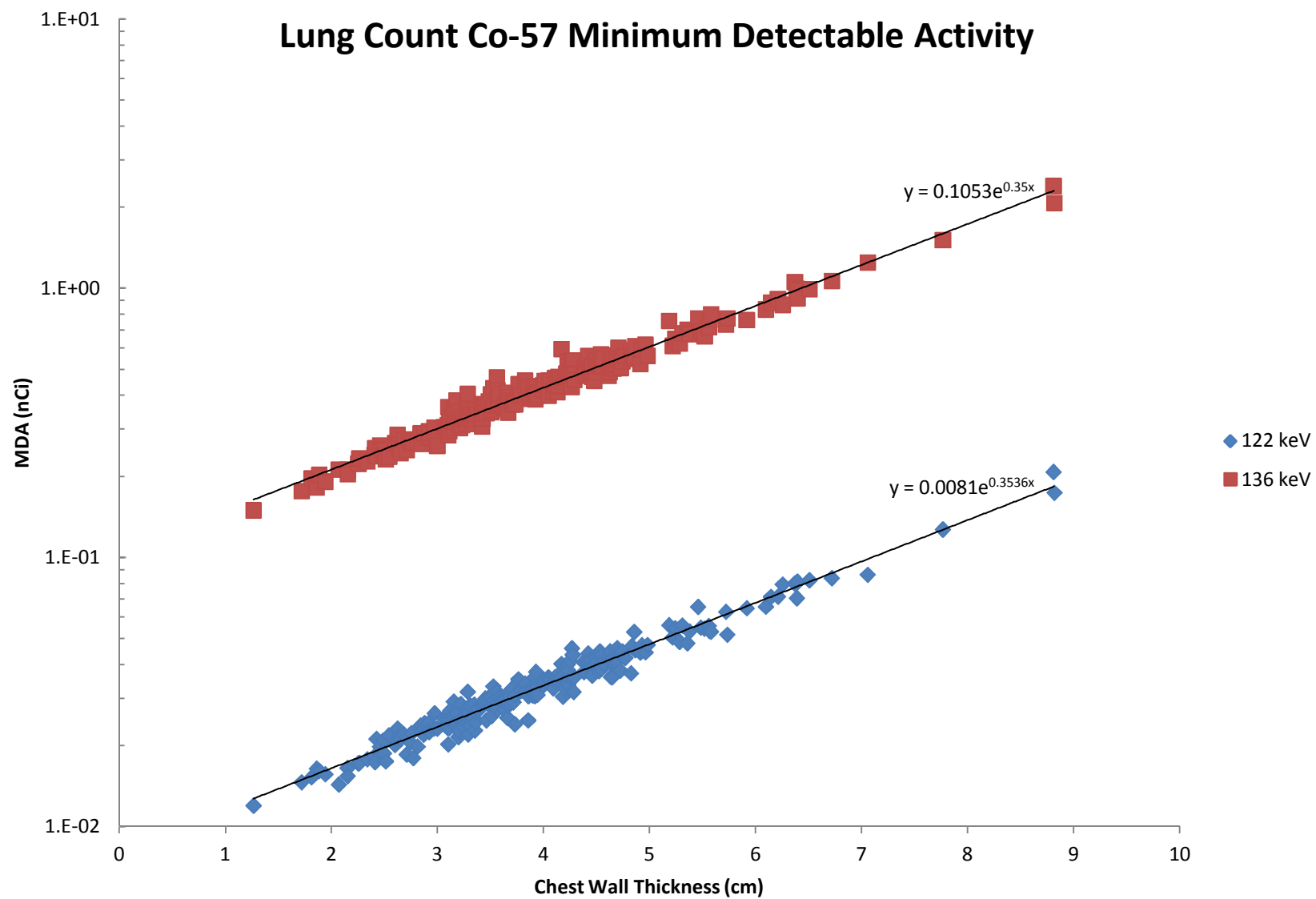


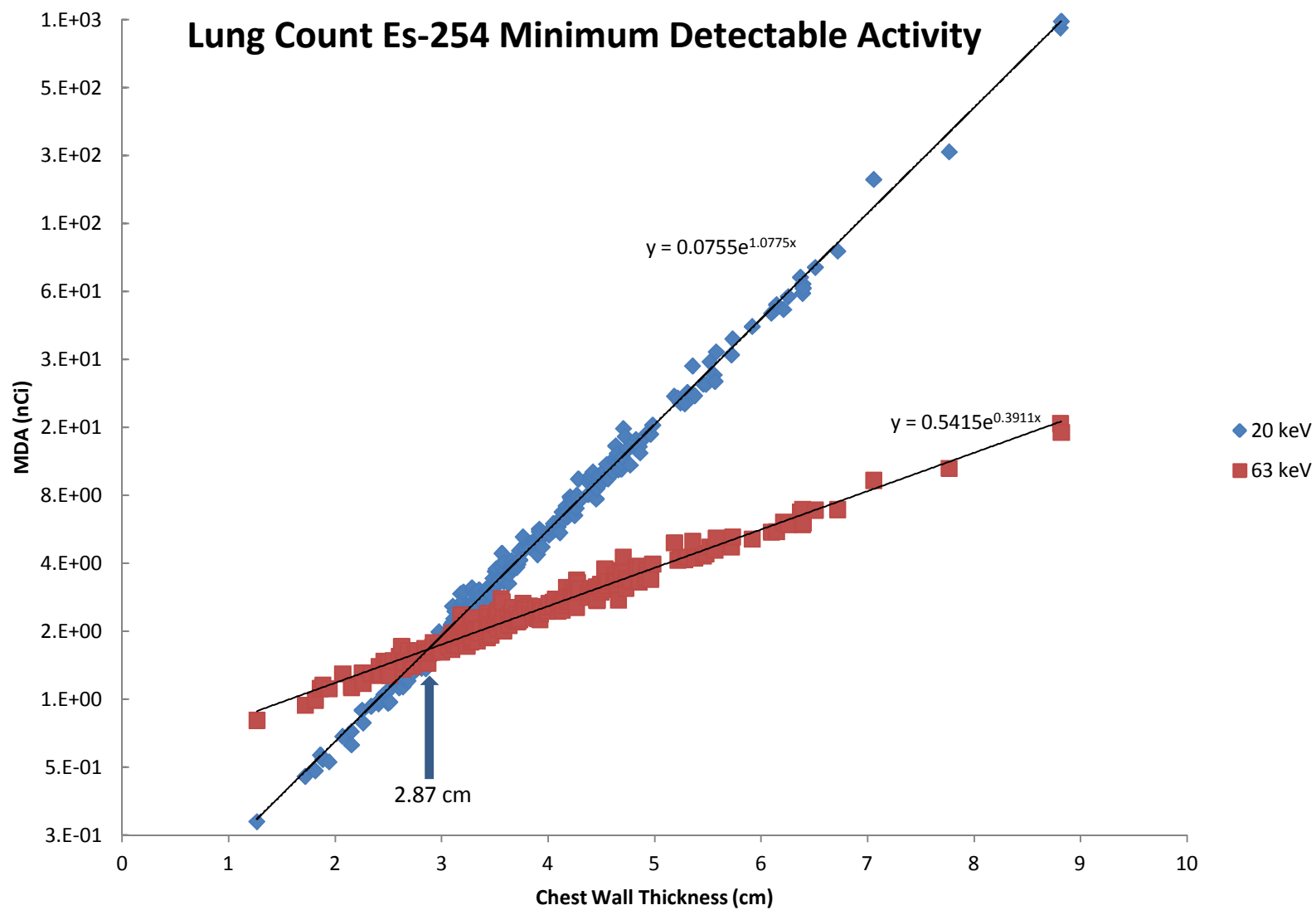
# Lung Count Cm-244 Minimum Detectable Activity

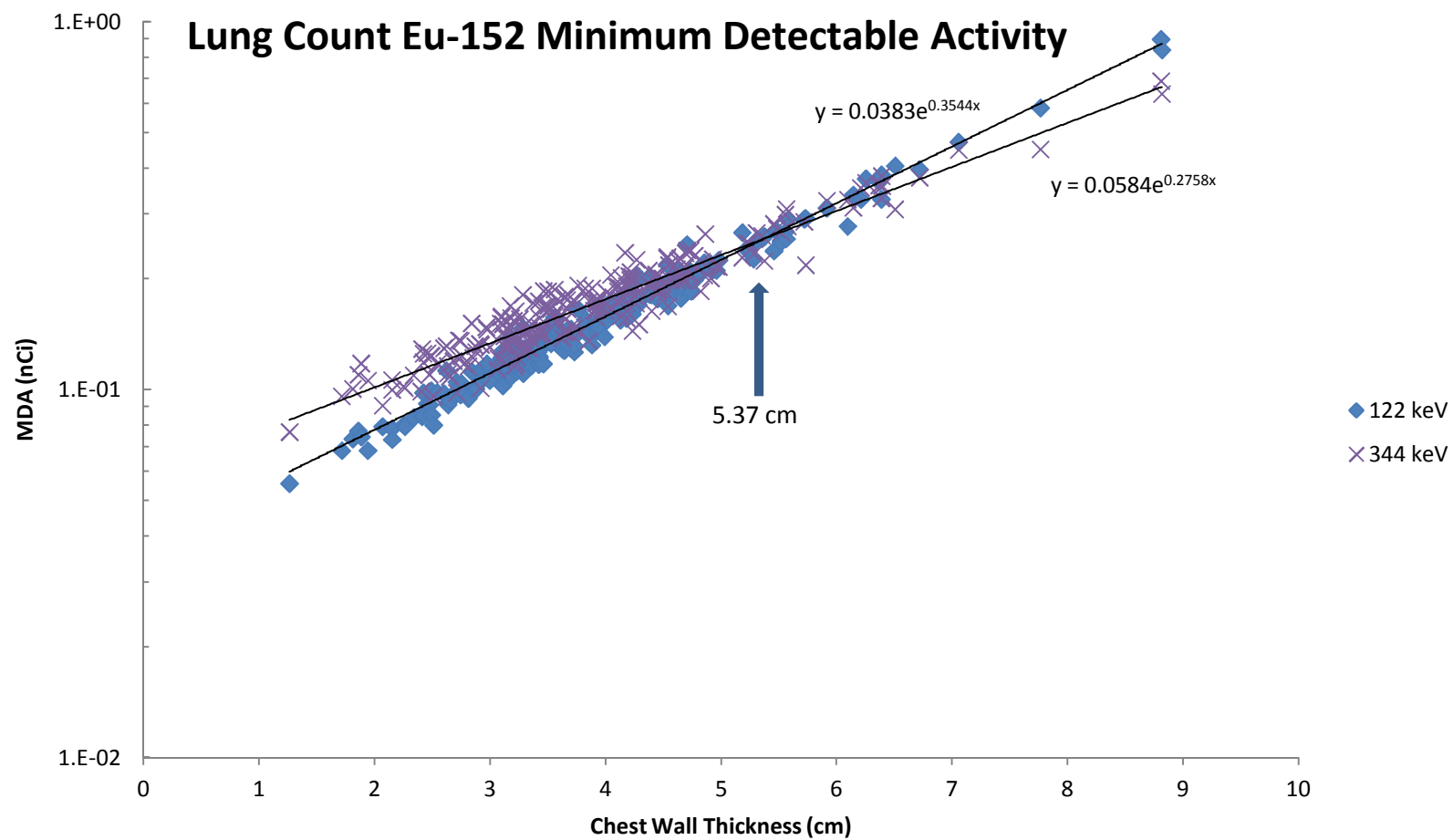


## Lung Count Cm-245 Minimum Detectable Activity

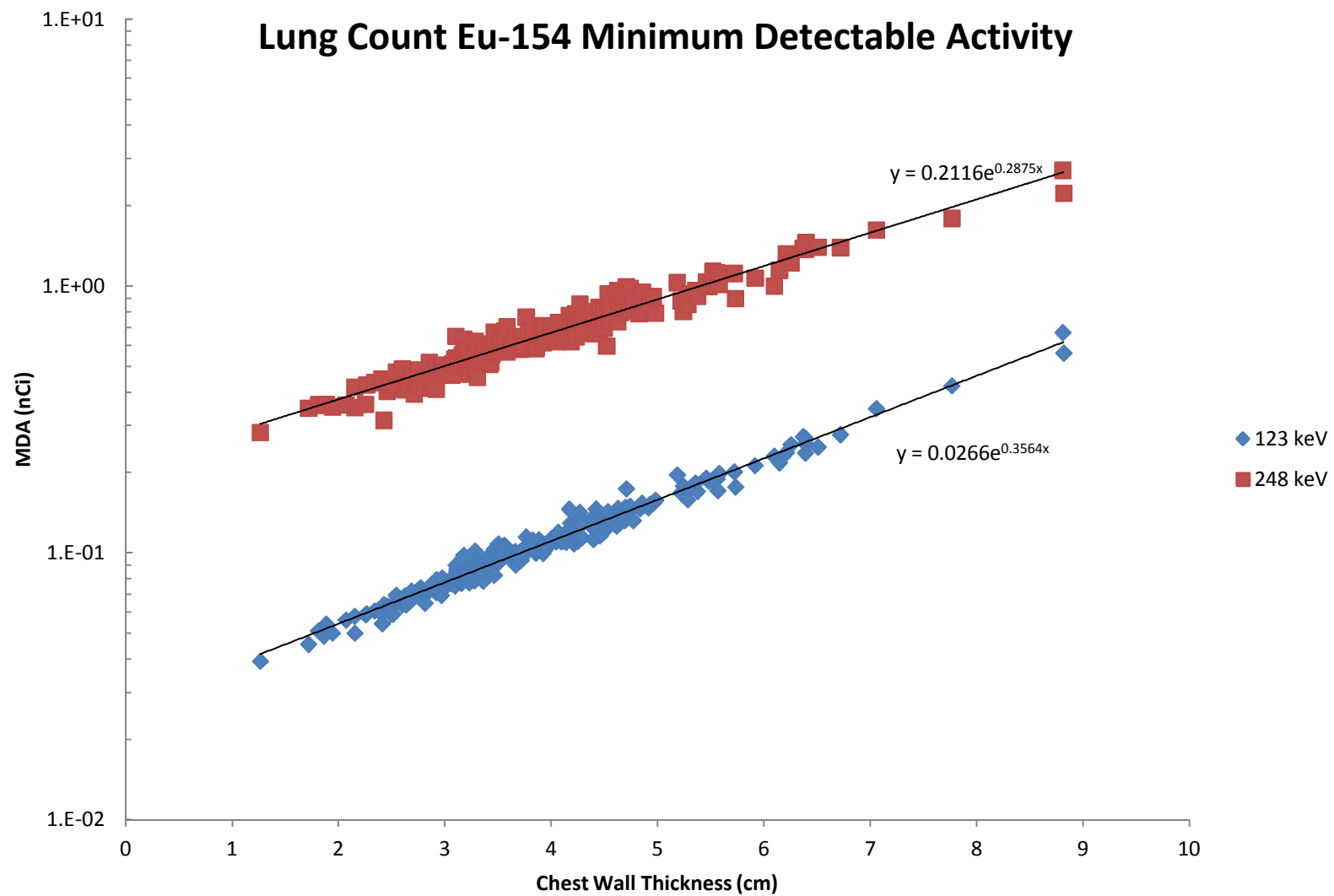




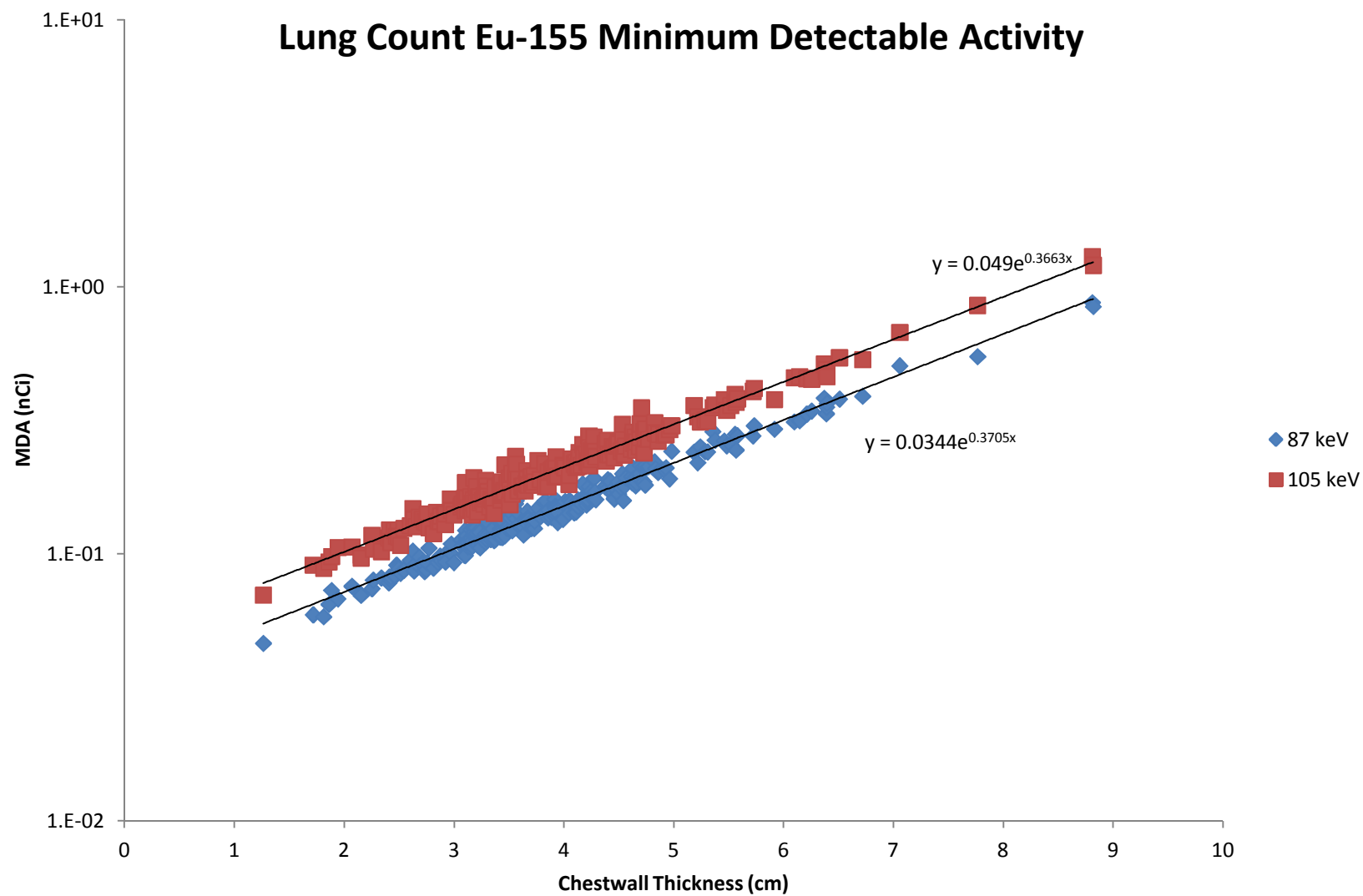




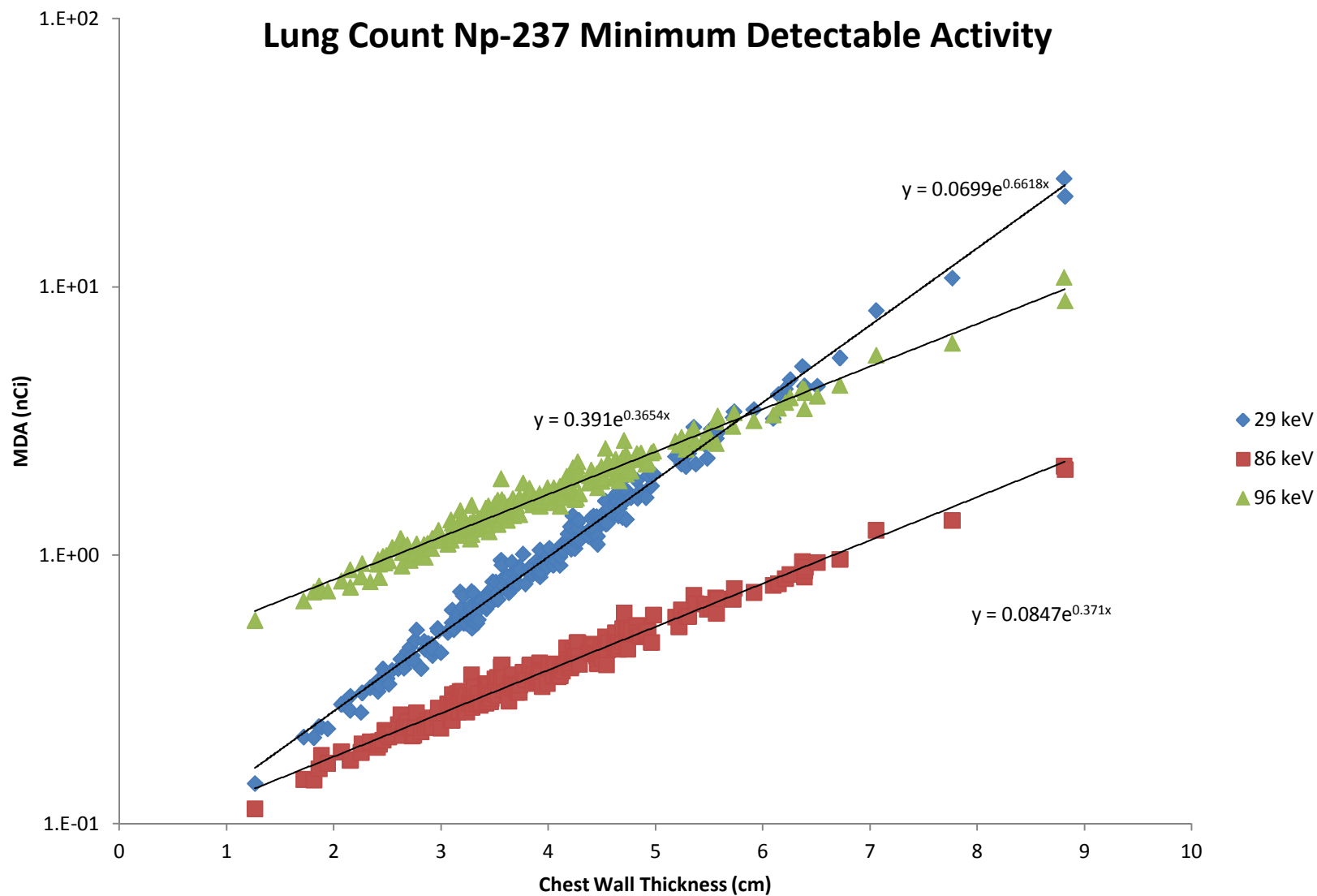
## Lung Count Eu-154 Minimum Detectable Activity



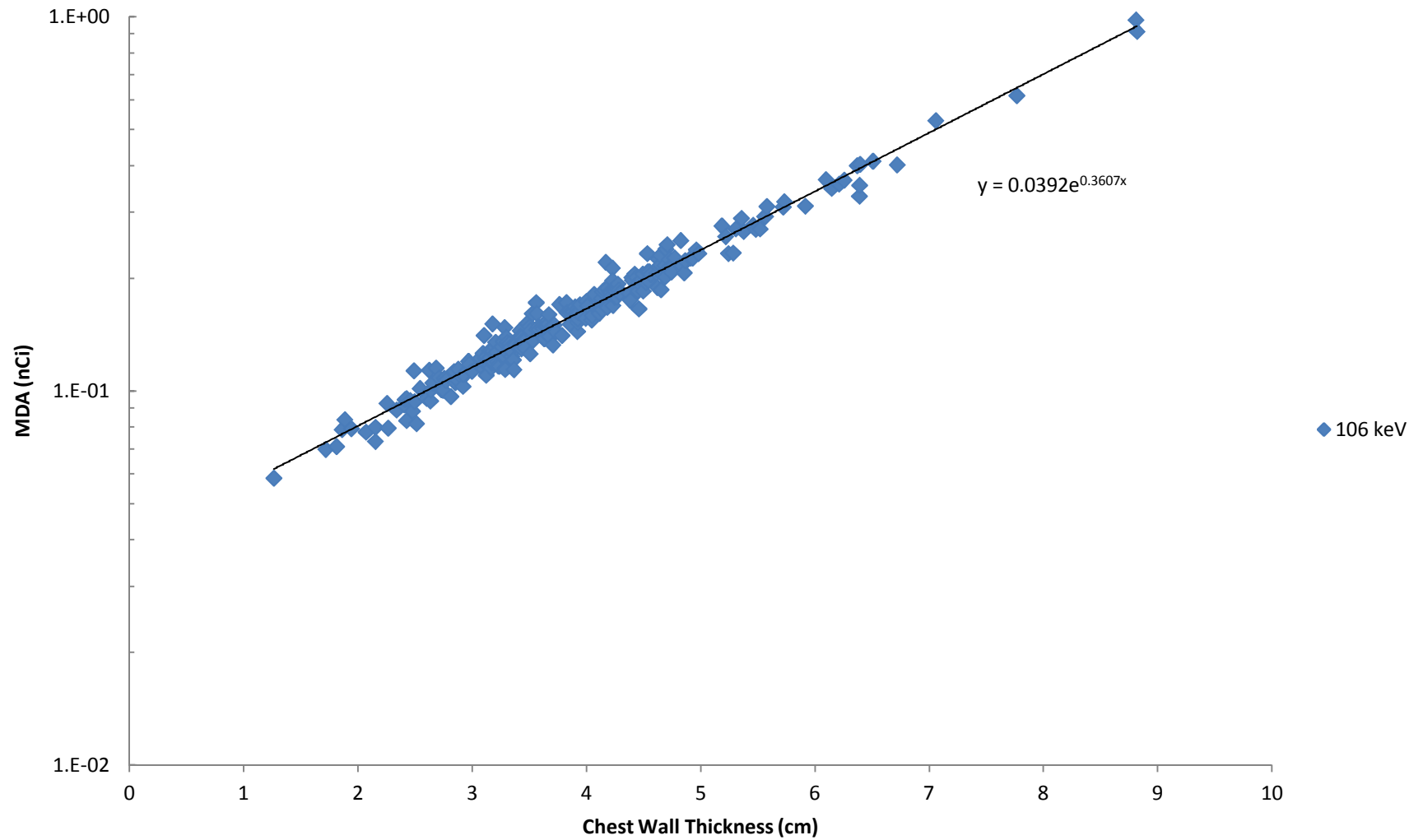


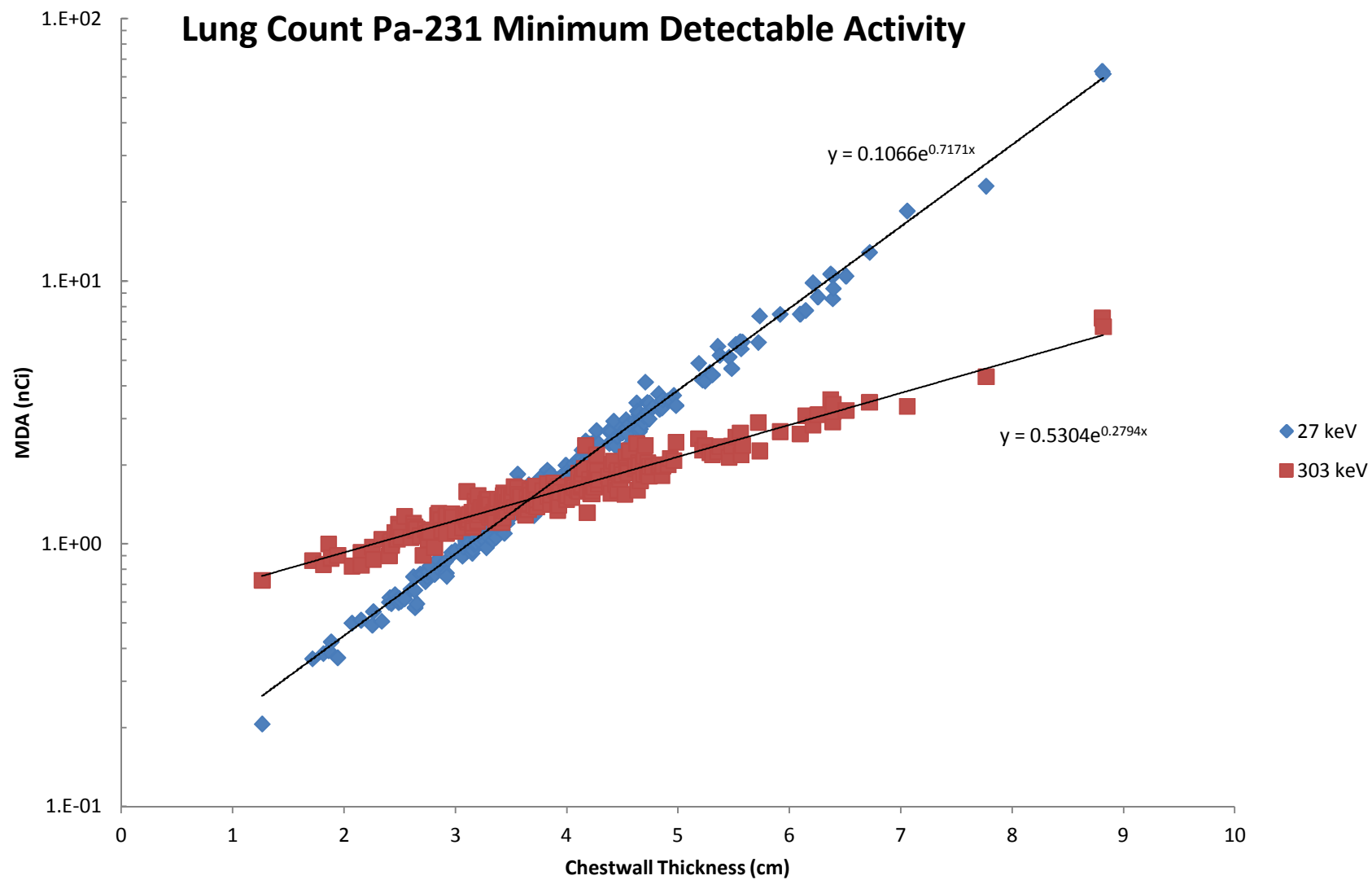


## Lung Count Np-237 Minimum Detectable Activity

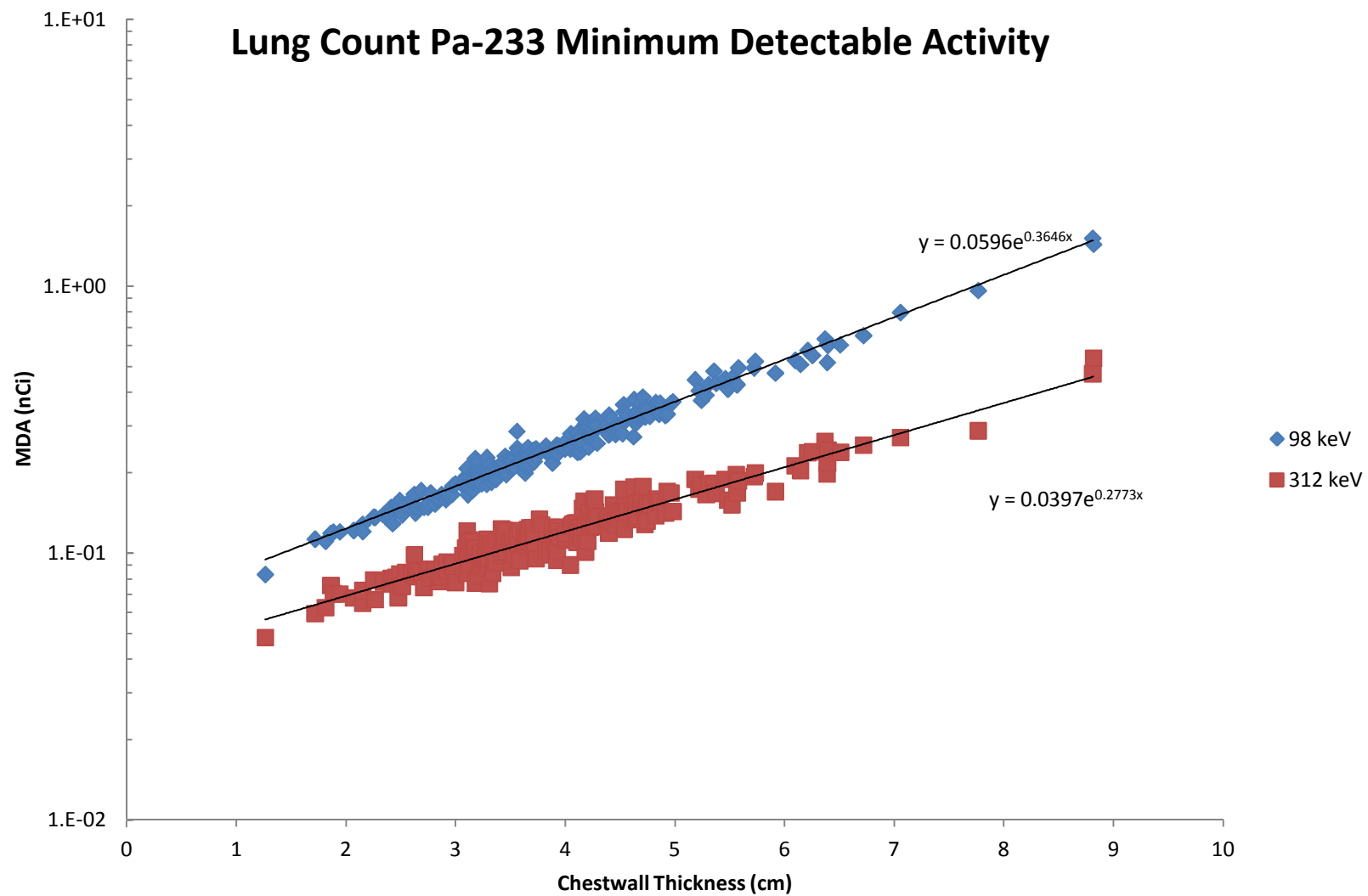


## Lung Count Np-239 Minimum Detectable Activity

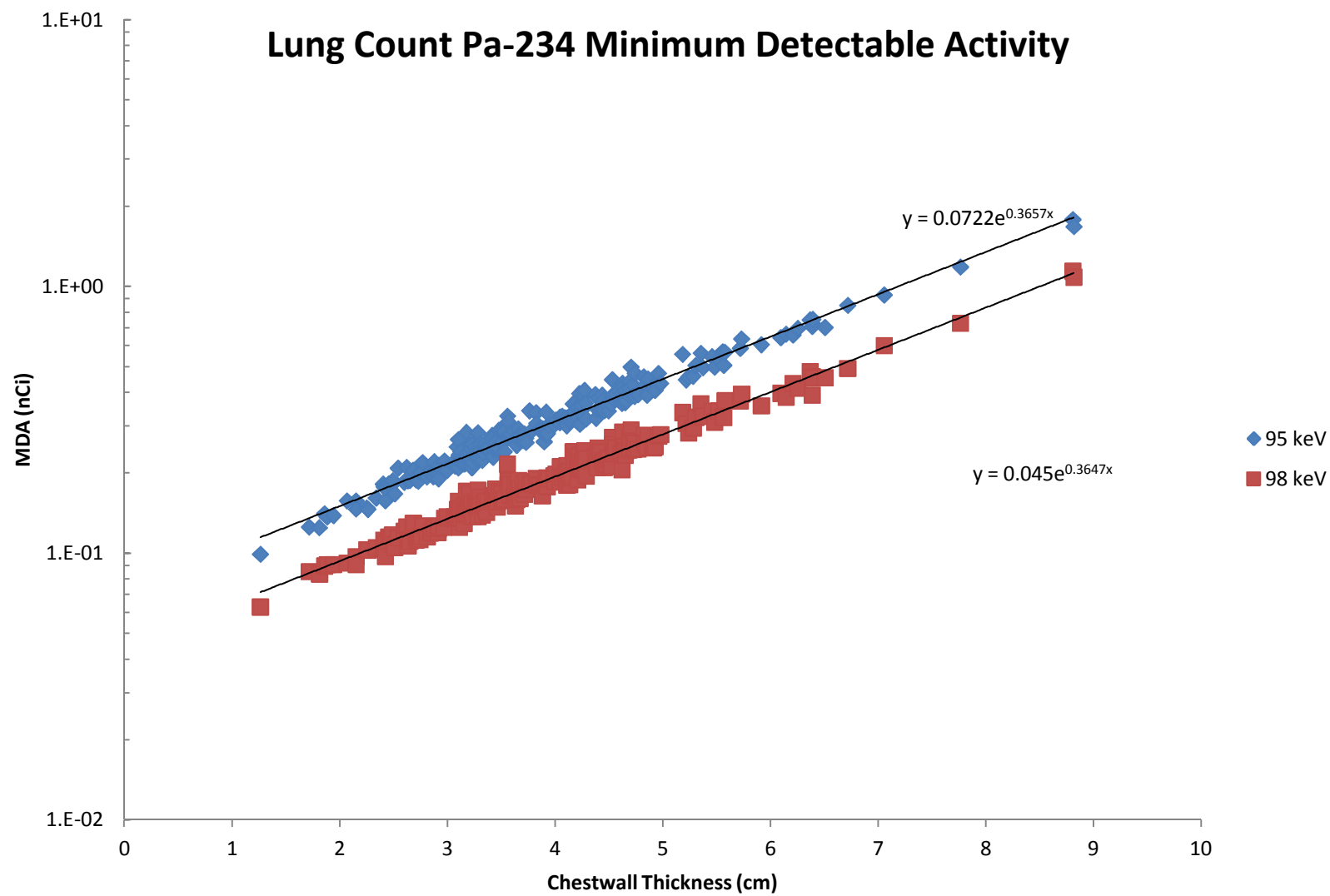




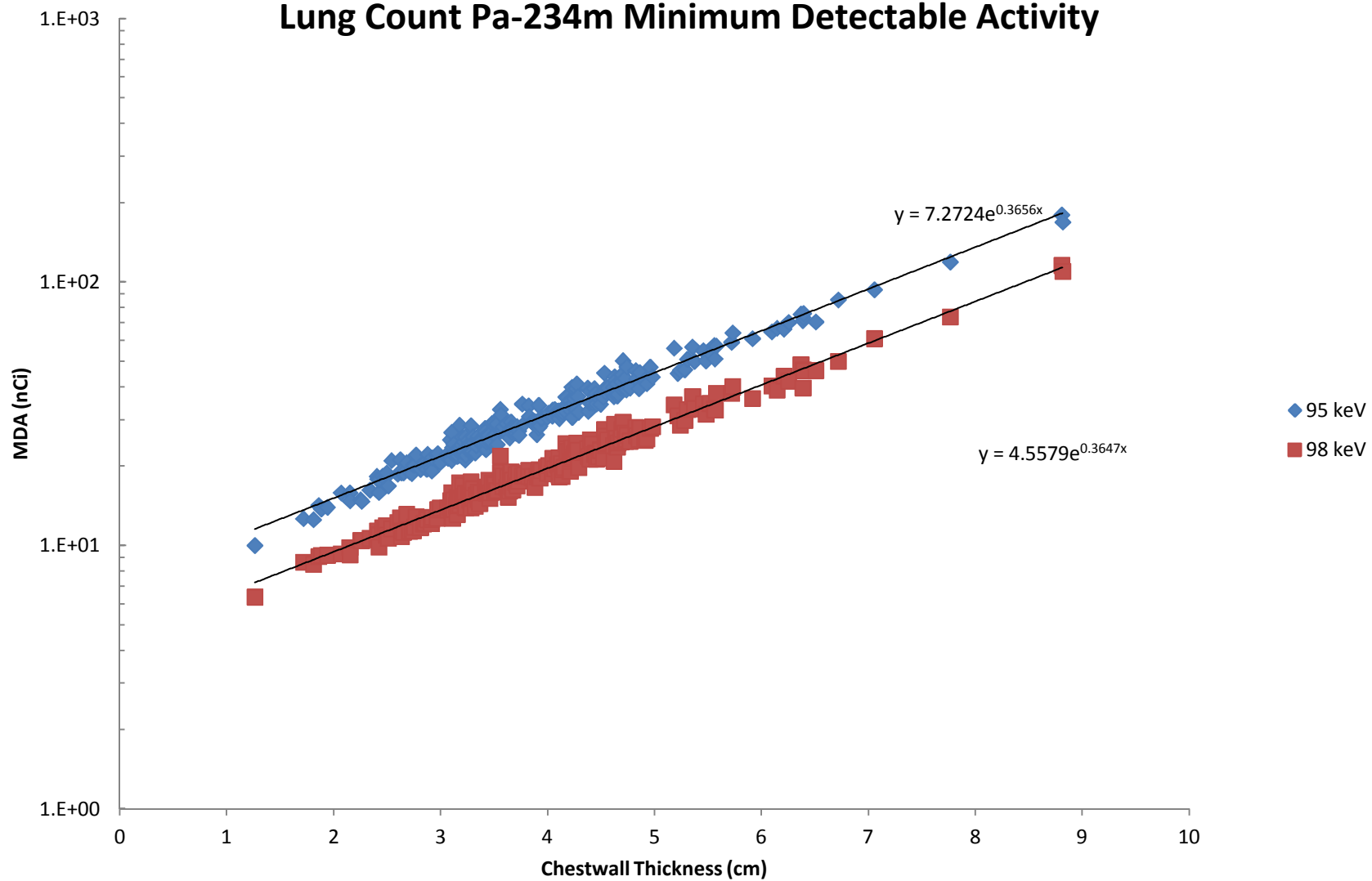
## Lung Count Pa-233 Minimum Detectable Activity



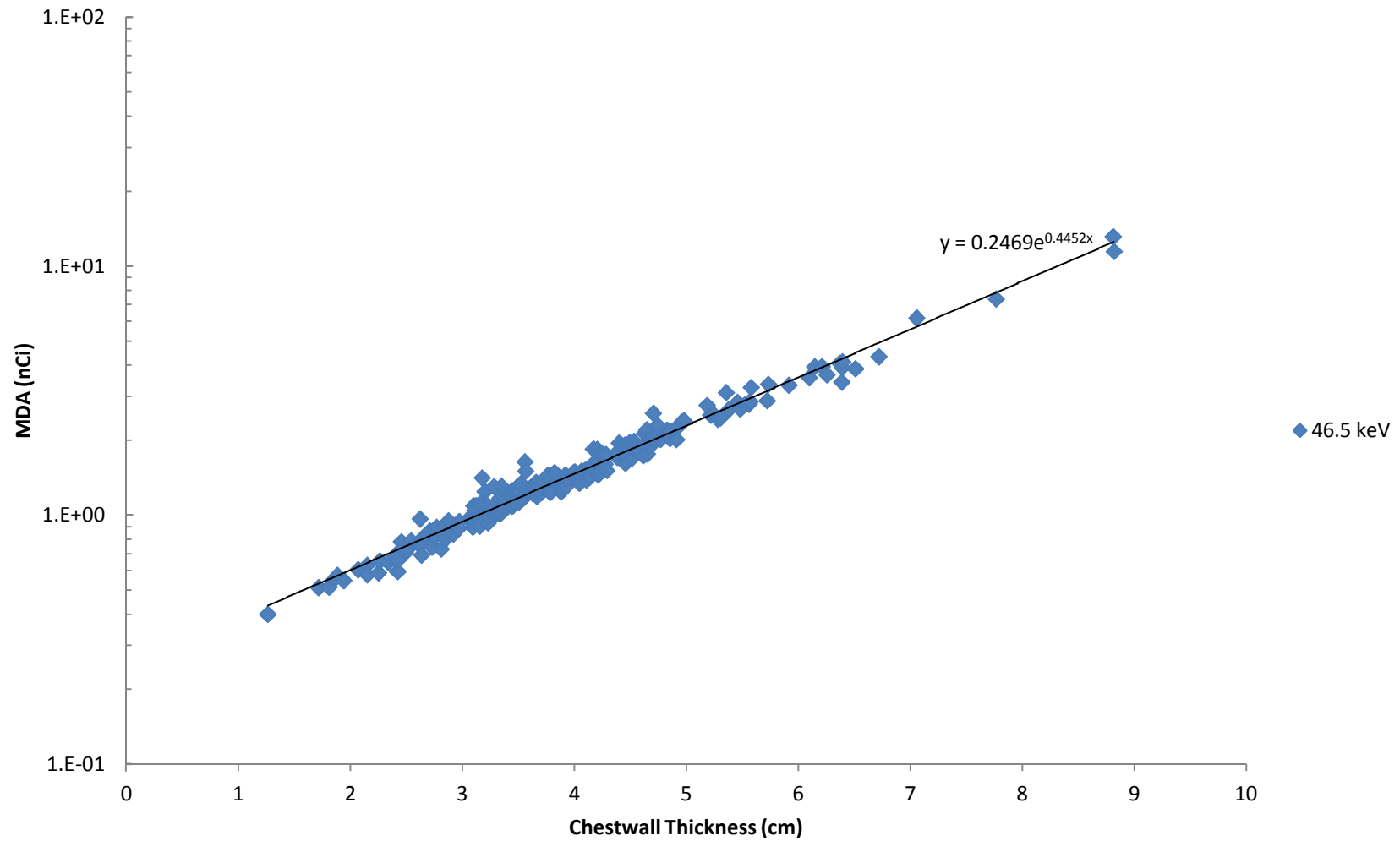
## Lung Count Pa-234 Minimum Detectable Activity



## Lung Count Pa-234m Minimum Detectable Activity

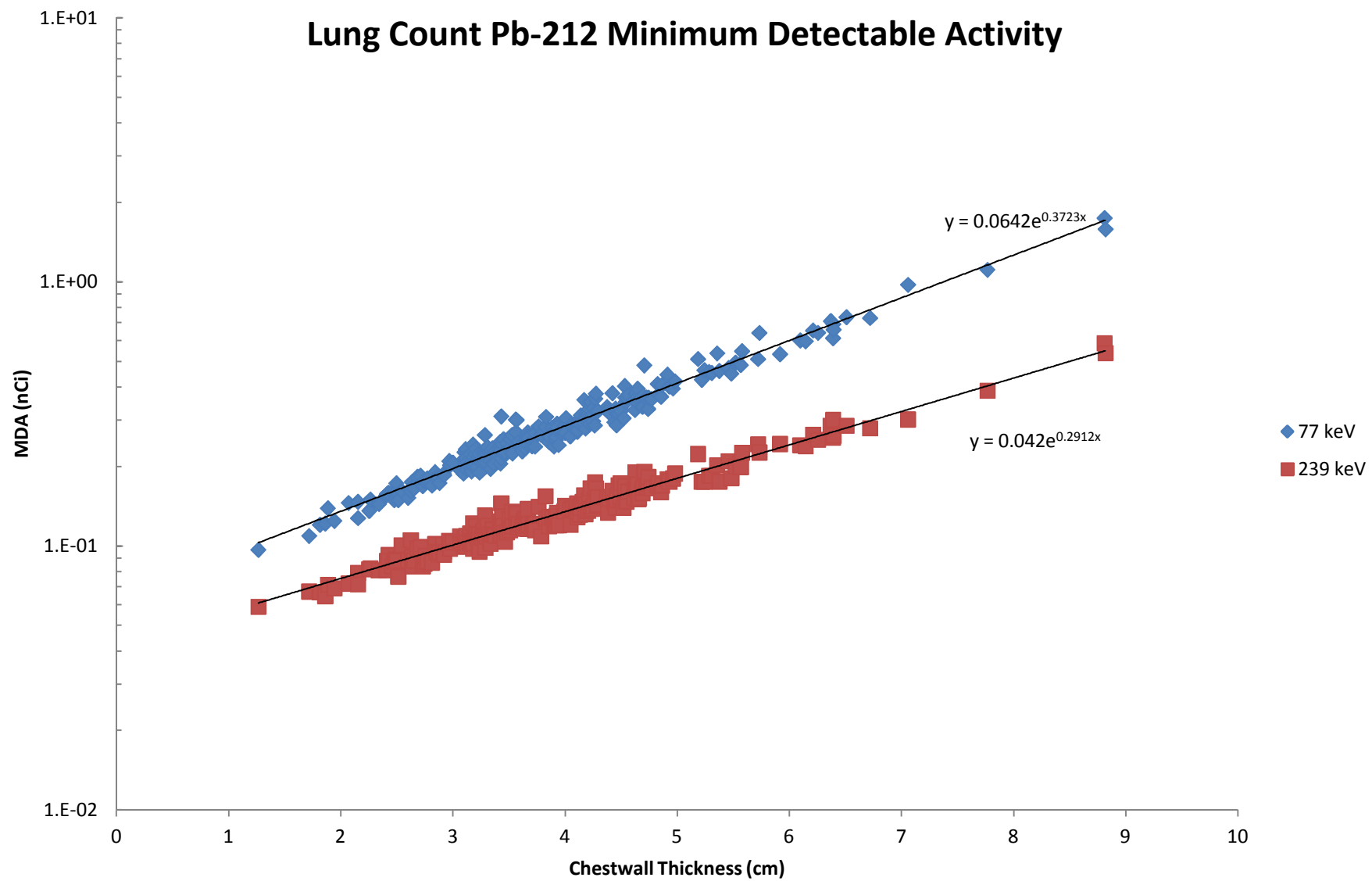


## Lung Count Pb-210 Minimum Detectable activity

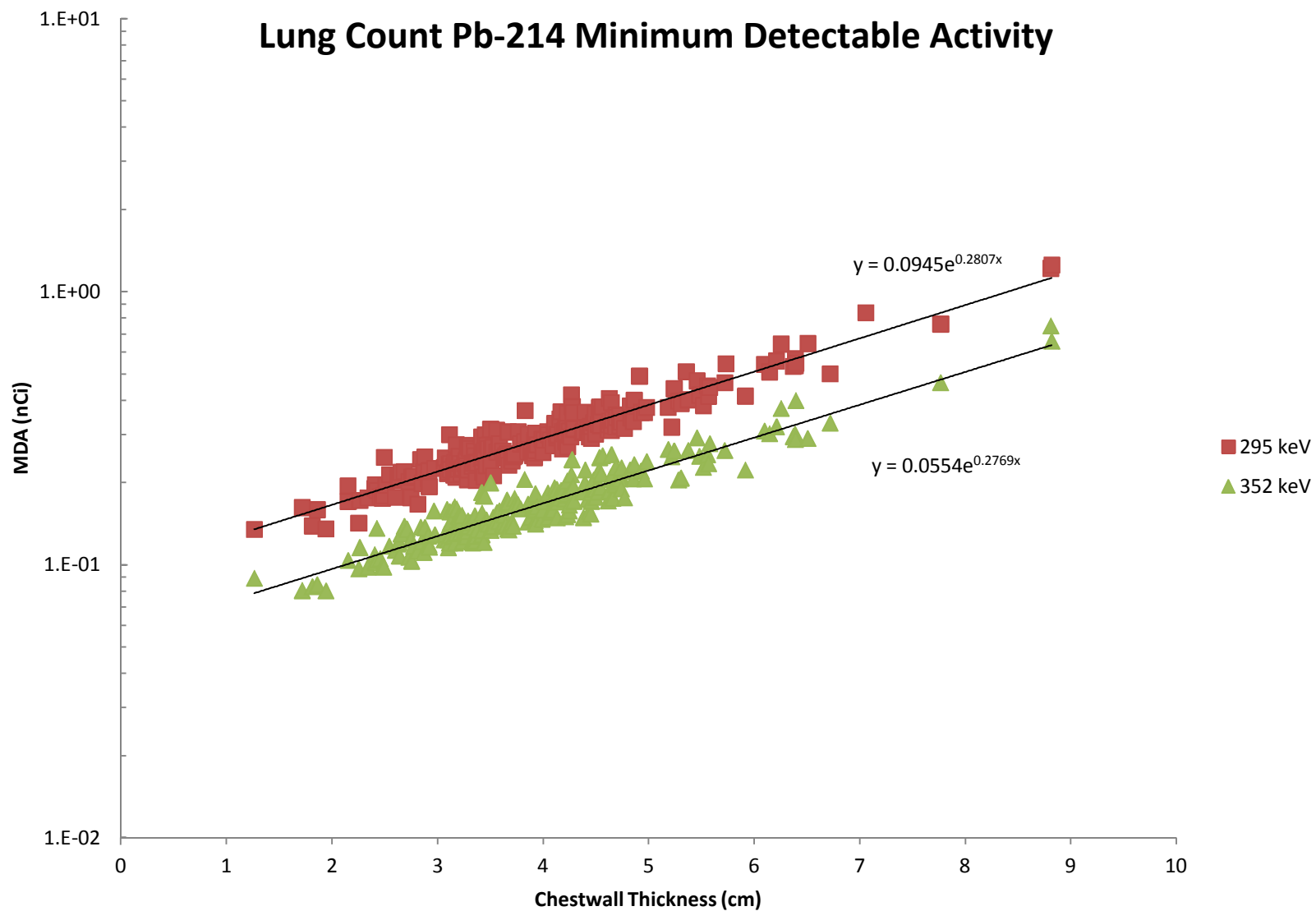




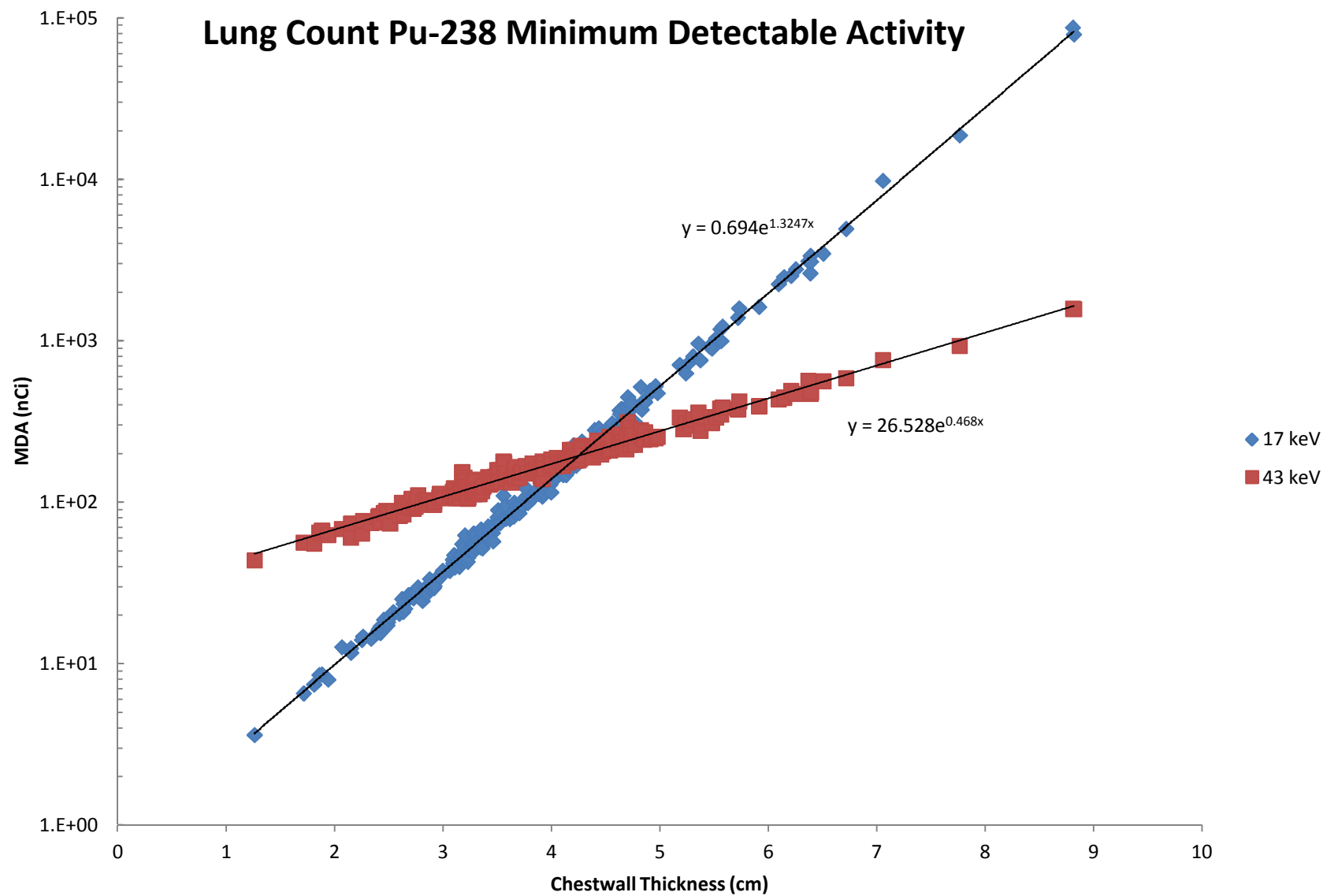
## Lung Count Pb-212 Minimum Detectable Activity



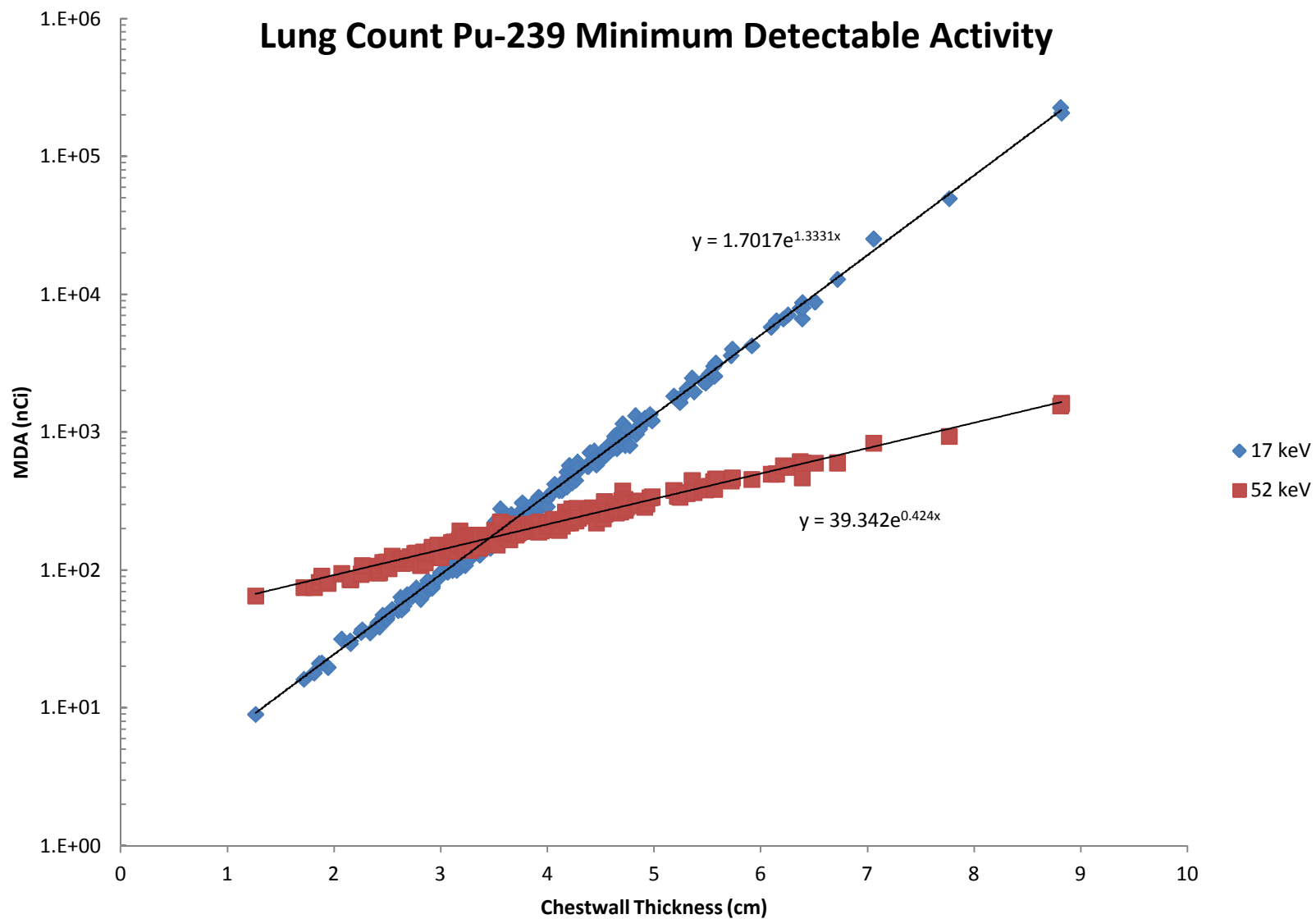
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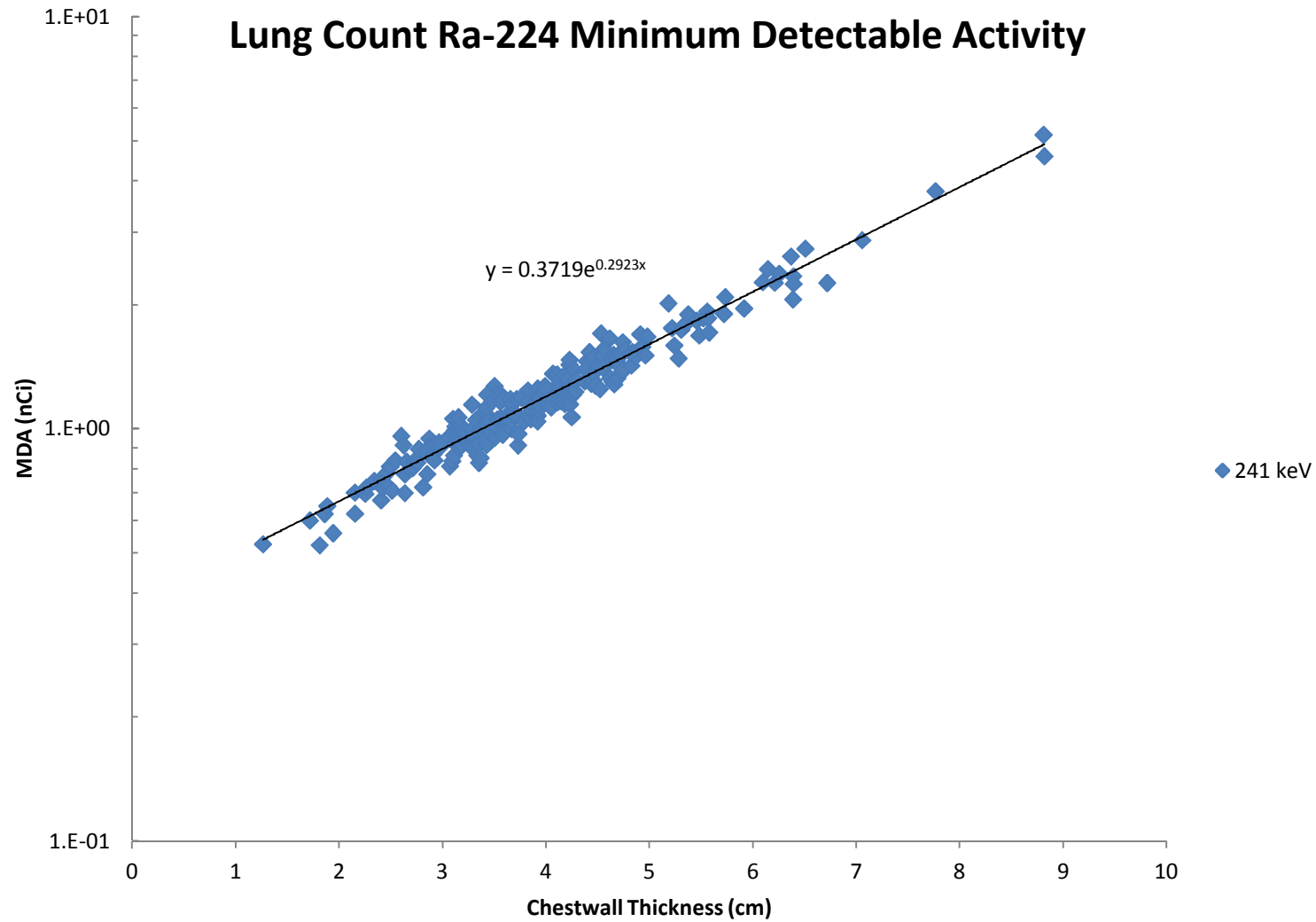
## Lung Count Pu-238 Minimum Detectable Activity

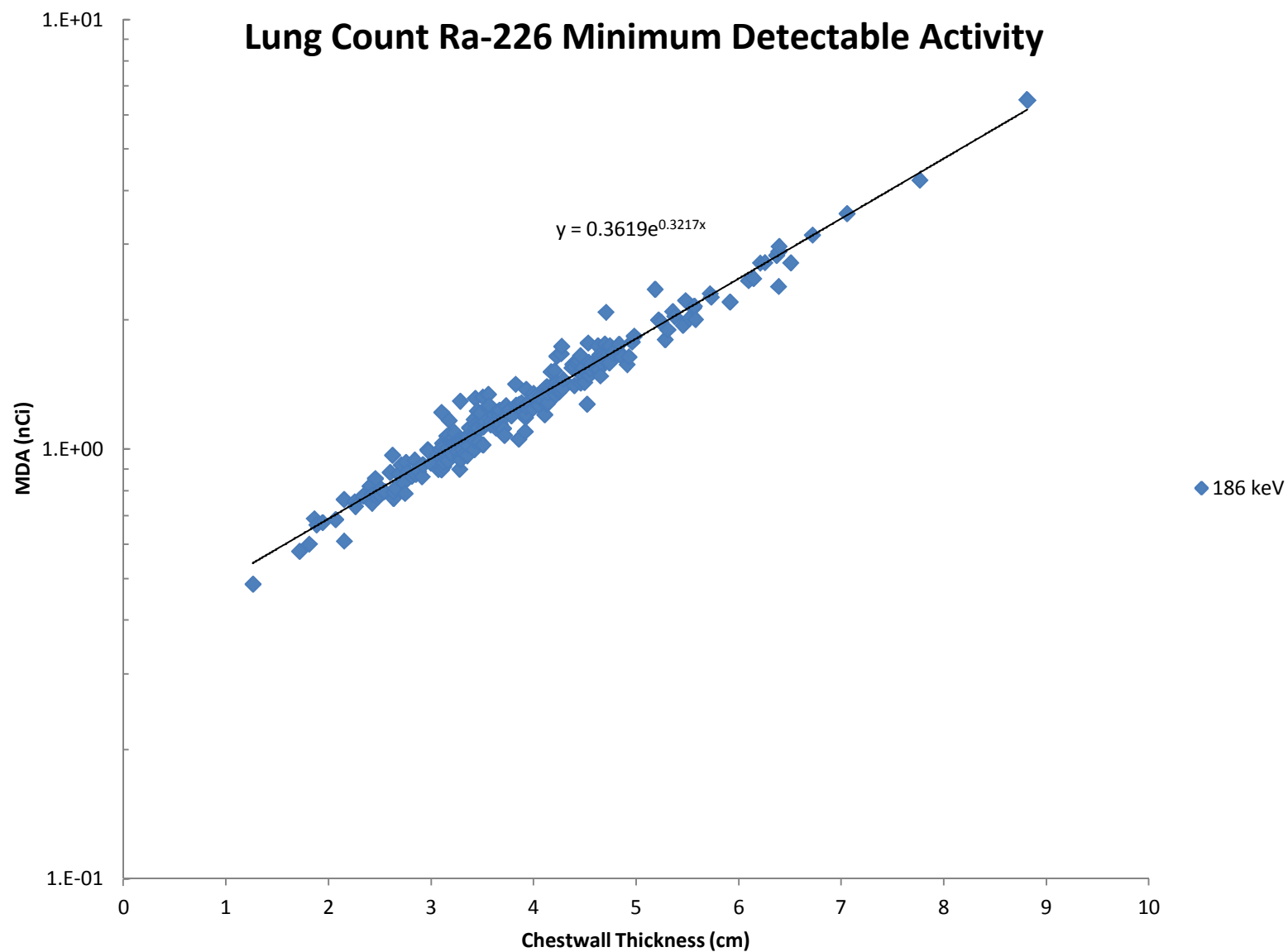


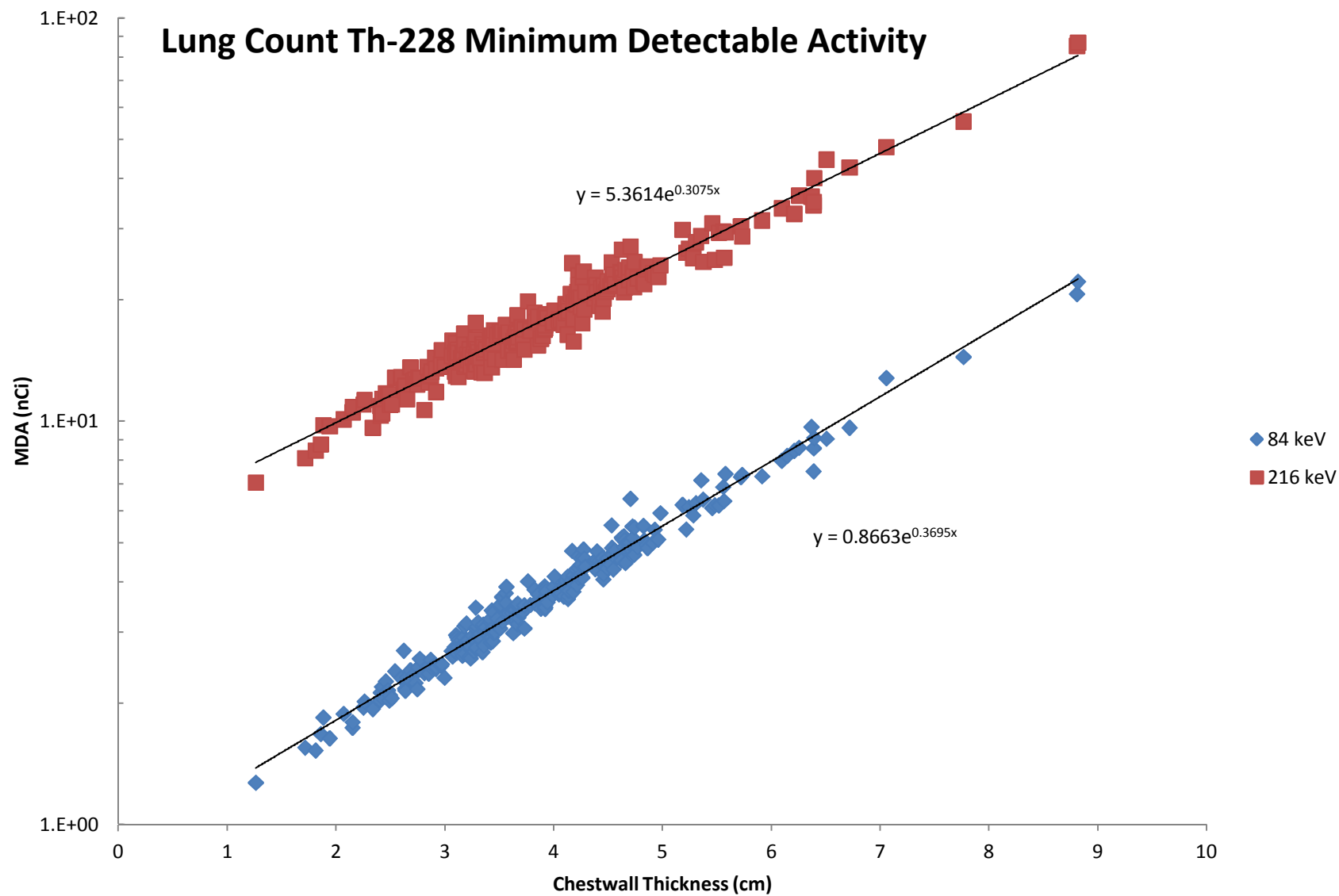
## Lung Count Pu-239 Minimum Detectable Activity

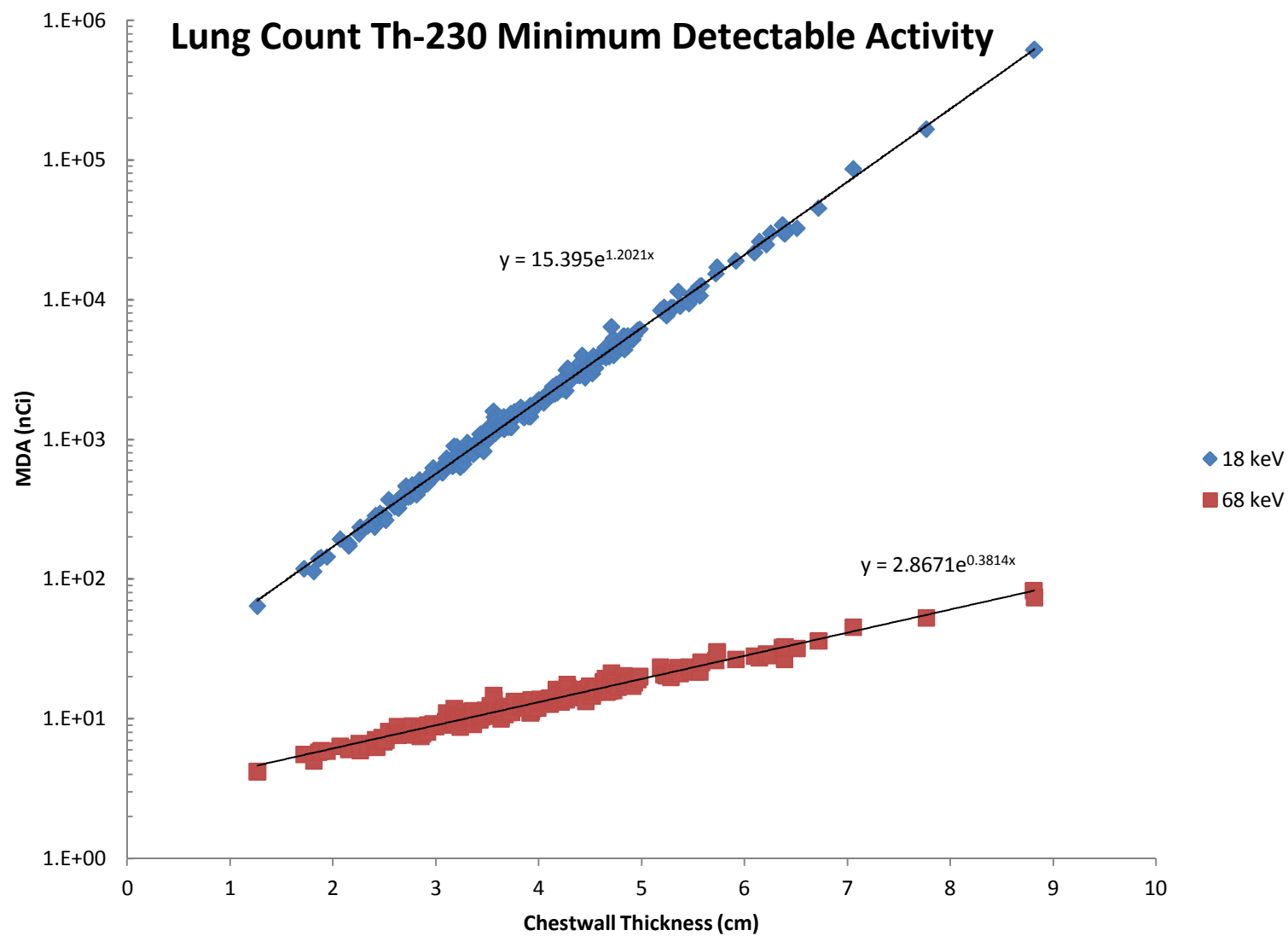


## Lung Count Ra-224 Minimum Detectable Activity

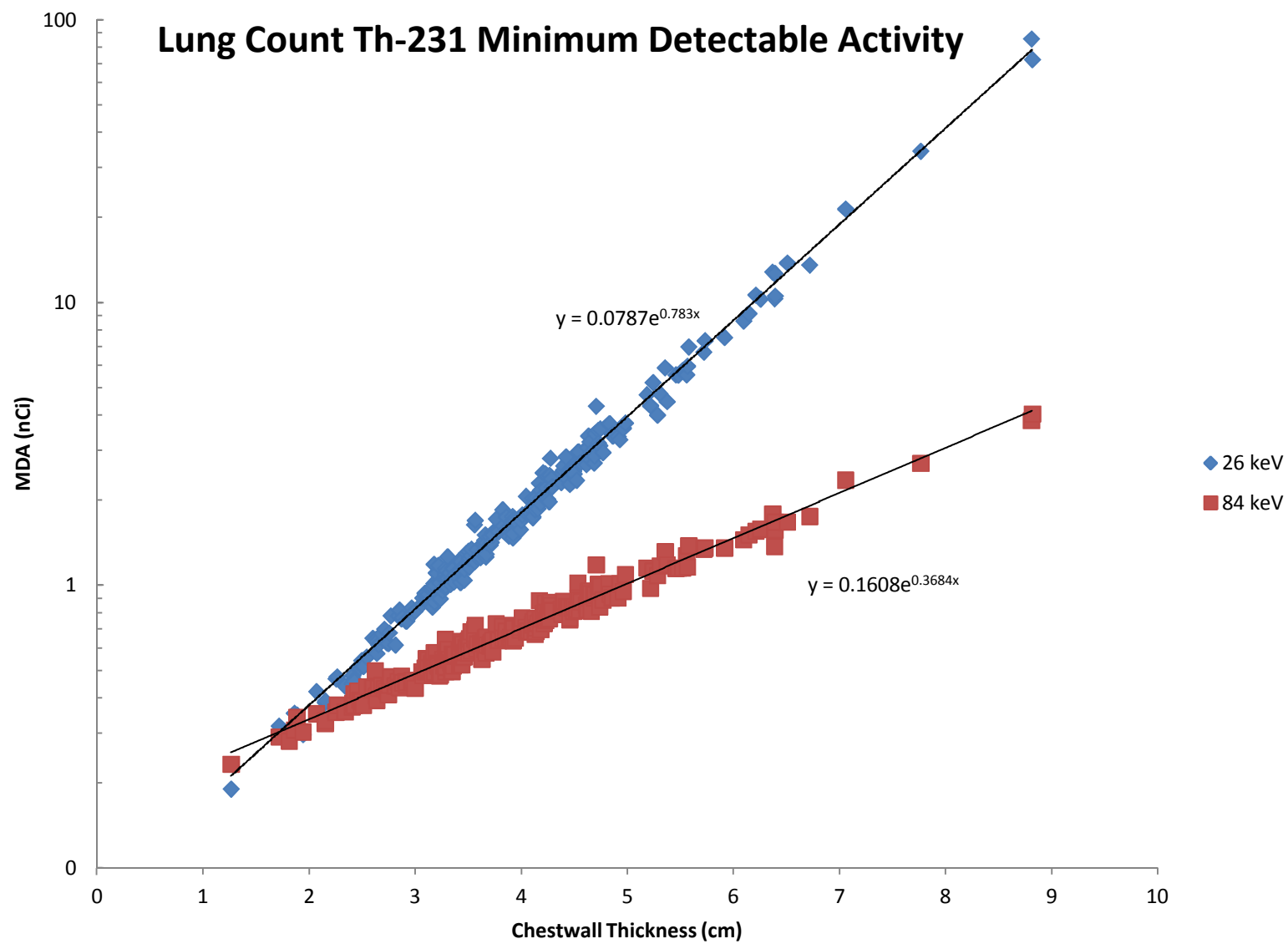




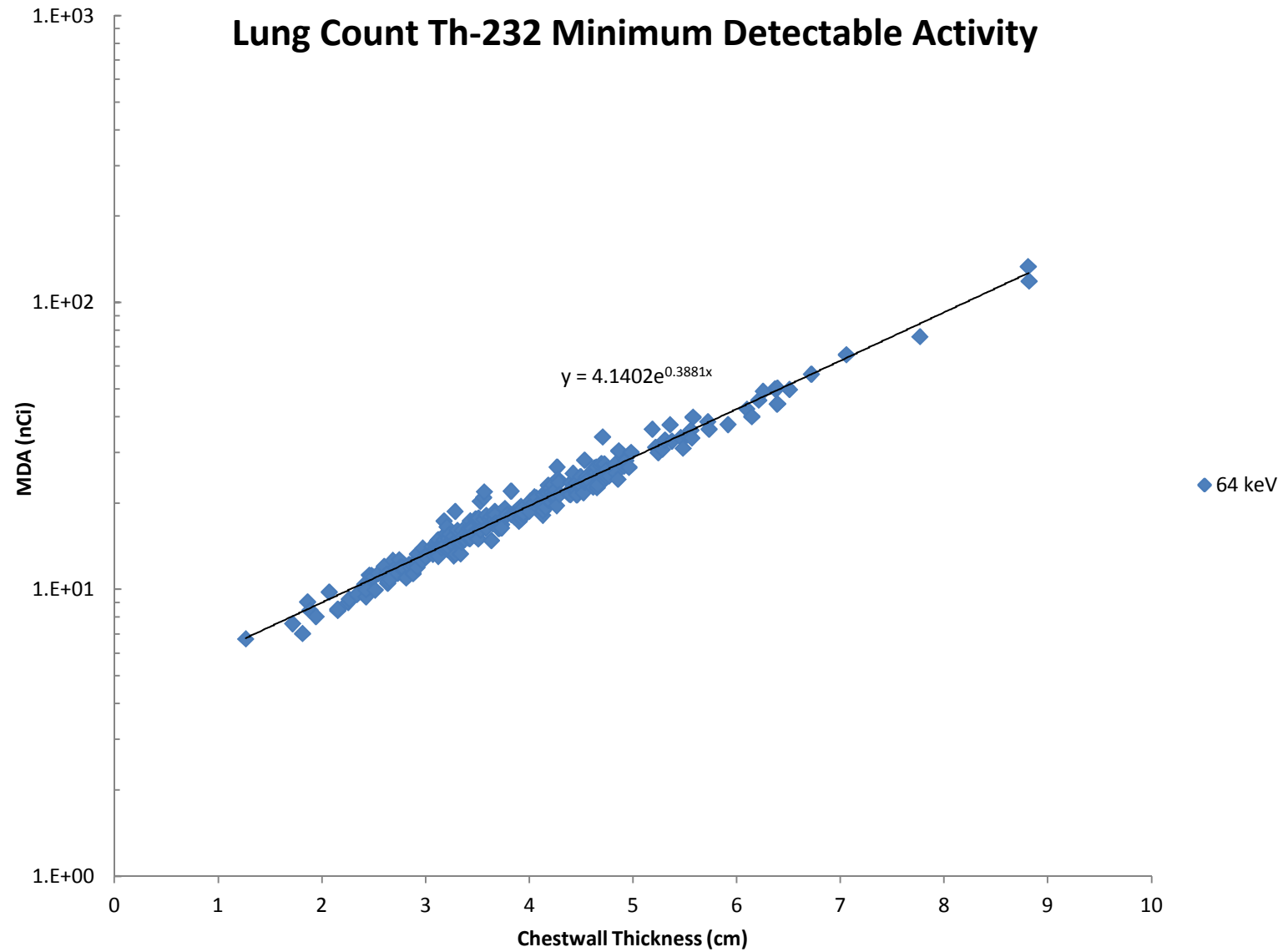


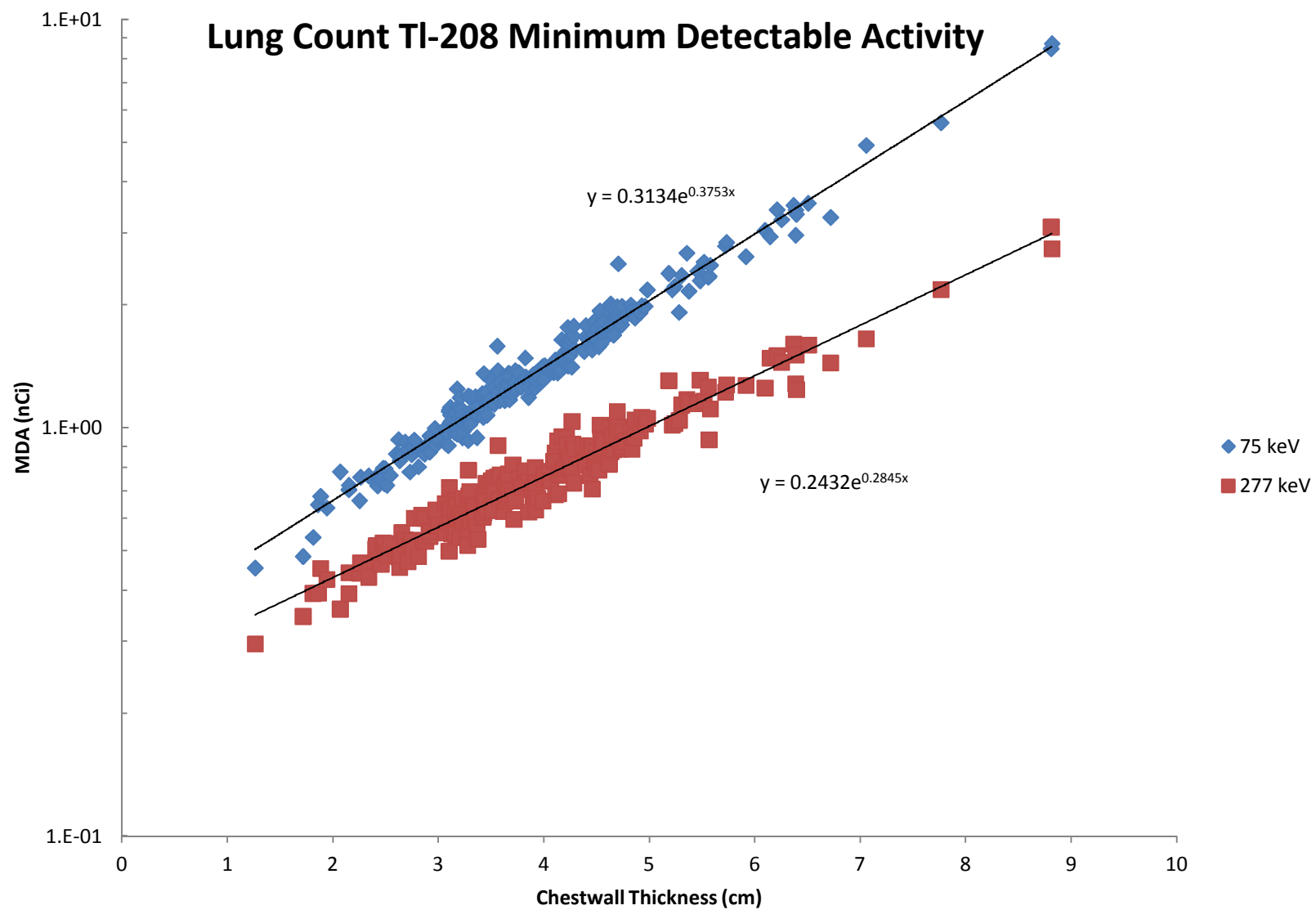


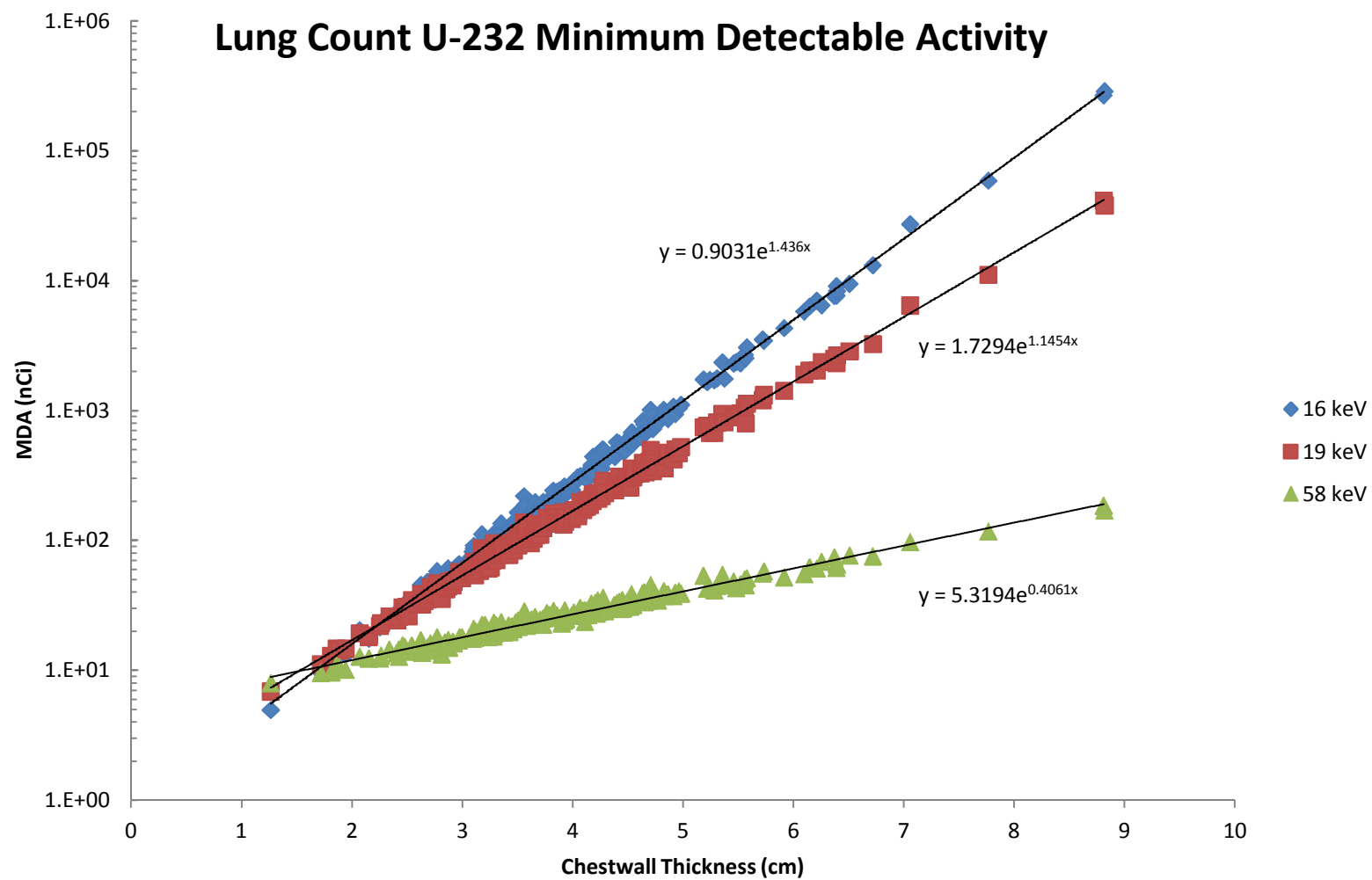




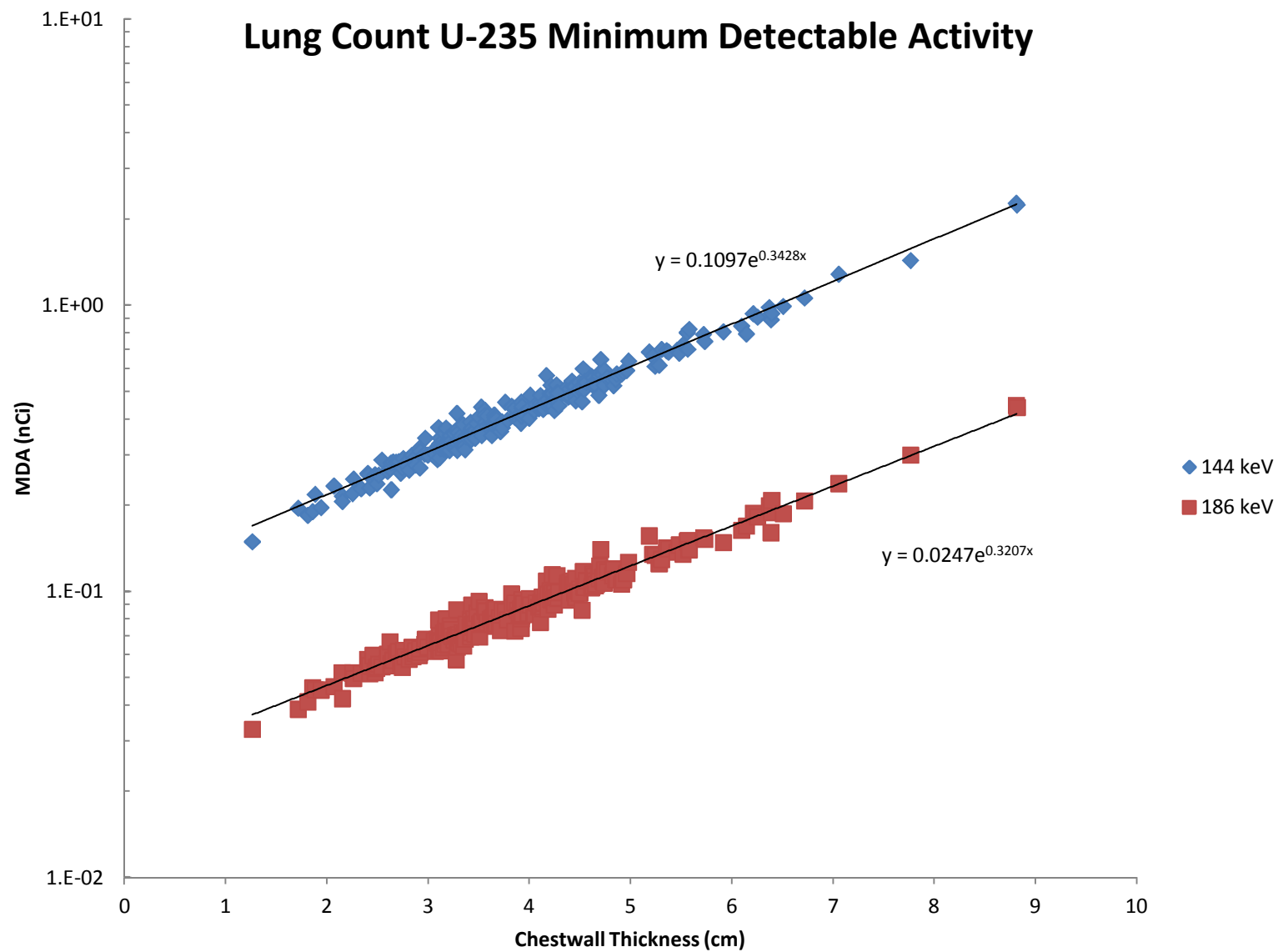
## Lung Count Th-232 Minimum Detectable Activity

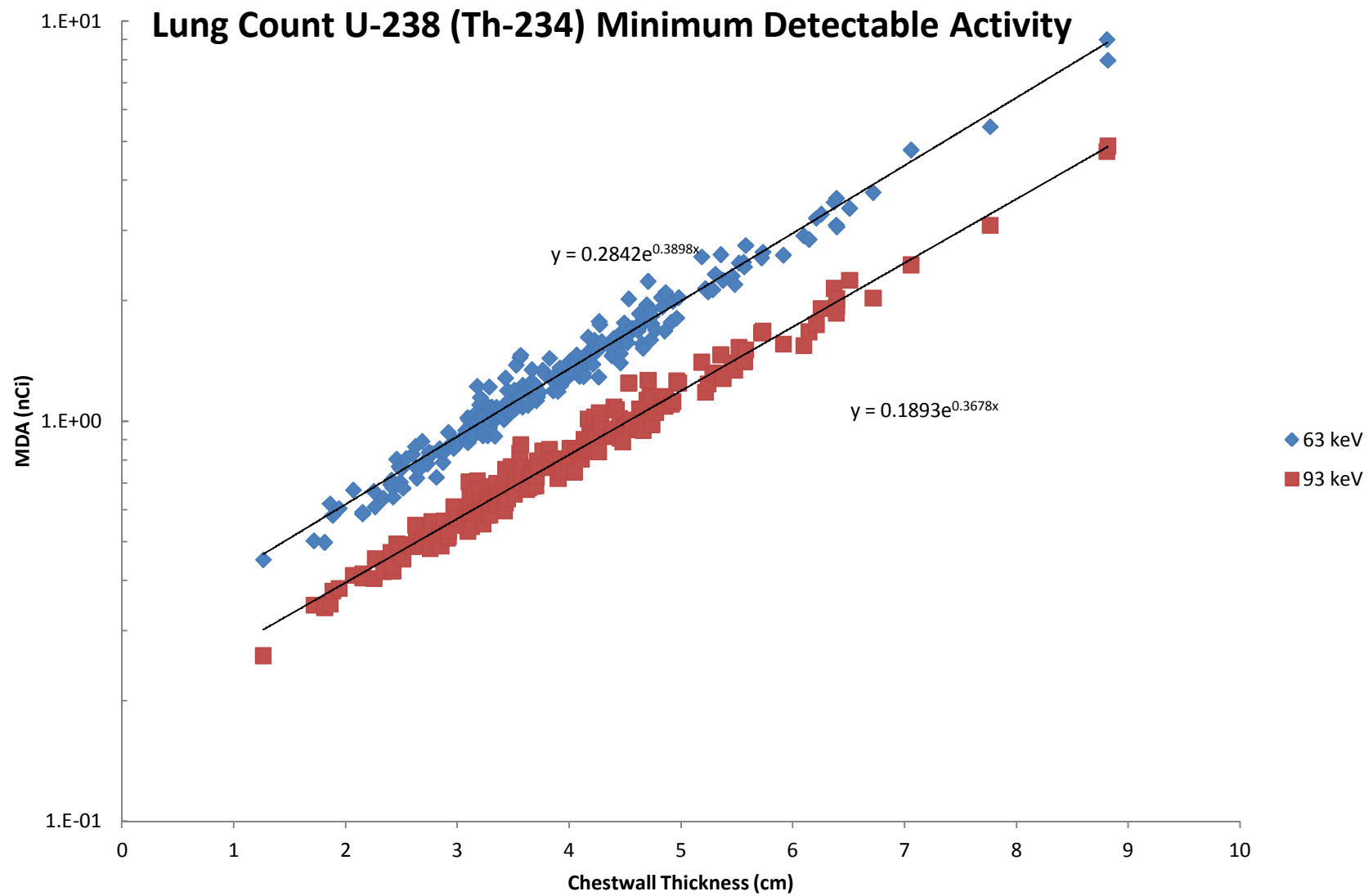






## Lung Count U-235 Minimum Detectable Activity





# **SCANNING BED WHOLE BODY COUNT MINIMUM DETECTABLE ACTIVITIES**



**Scanning Bed Whole Body Counter Average Minimum Detectable Activity.**

| <b>Radionuclide</b> | <b>MDA<br/>(nCi)</b> | <b>+/-1s</b> |
|---------------------|----------------------|--------------|
| Ac-228              | 3.61                 | 0.29         |
| Ba-133              | 1.06                 | 0.13         |
| Bi-207              | 0.60                 | 0.08         |
| Bi-212              | 10.2                 | 1.31         |
| Bi-214              | 5.49                 | 0.68         |
| Bk-245              | 1.98                 | 0.57         |
| Bk-250              | 1.22                 | 0.20         |
| Cf-249              | 1.04                 | 0.11         |
| Cm-241              | 0.89                 | 0.10         |
| Cm-243              | 5.07                 | 1.57         |
| Cm-245              | 6.81                 | 2.12         |
| Co-57               | 1.16                 | 0.13         |
| Co-60               | 0.46                 | 0.09         |
| Cs-134              | 0.72                 | 0.11         |
| Cs-137              | 0.93                 | 0.10         |
| Eu-152              | 2.39                 | 0.42         |
| Eu-154              | 1.52                 | 0.27         |
| Eu-155              | 5.37                 | 2.04         |
| I-131               | 0.85                 | 0.09         |
| K-40                | 3.71                 | 1.09         |
| Na-24               | 0.54                 | 0.10         |
| Np-237              | 13.3                 | 5.09         |
| Np-239              | 4.16                 | 1.30         |
| Pa-231              | 26.5                 | 2.9          |
| Pa-233              | 1.94                 | 0.20         |
| Pa-234              | 3.99                 | 0.70         |
| Pa-234m             | 71.5                 | 9.43         |
| Pb-212              | 2.62                 | 0.23         |
| Pb-214              | 2.89                 | 0.29         |
| Ra-224              | 24.4                 | 3.1          |
| Ra-226              | 27.2                 | 2.7          |
| Th-231              | 23.9                 | 2.7          |
| Th-234              | 26.2                 | 4.2          |
| Tl-208              | 4.91                 | 0.61         |
| U-235               | 1.84                 | 0.18         |
| Zr-95               | 1.01                 | 0.17         |